JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. XXVI. NOVEMBER, 1914. No. 4.

The Society as a body is not responsible for statements made by individual members.

COUNCIL OF THE SOCIETY

(Under whose supervision this number is published).

Rear Admiral J. R. EDWARDS, U. S. N. Engineer-in-Chief R. S. GRIFFIN, U. S. N.

Captain B. C. BRYAN, U. S. N. Commander S. S. ROBISON, U. S. N.

Lieutenant Commander H. C. DINGER, U. S. N.

PROBLEMS IN SCREW PROPULSION.

FORECASTING RESULTS.—CRITICISM OF DESIGNS.—BIRTH OF CAVITATION.

BY CAPTAIN C. W. DYSON, U. S. N., MEMBER.

In addition to preparing original designs of propellers, it usually falls to the lot of the marine engineer to be placed in a position where he is called upon to pass judgment on the designs of propellers submitted by others.

Such problems differ from those of original design in that the diameter, pitch, projected area ratio and form of projected area are already fixed, these quantities having to be determined in the other case.

Beginning with these fixed quantities may be designated as attacking the problem from the rear, and it is the intention of the writer in what follows to show how a close approximation to actual performance may be obtained by the use of the propeller charts already presented by him in this Journal.

In preparing to attack the problem an estimate of the stand-

ard projected area form equivalent to that of the proposed propeller must be made, bearing always in mind the fact that the outer third of the projected form is of greater value than the remainder of the blade in governing performance. On this account, in order to insure against underestimating power required, blades slightly narrower at the tips than the standard form may be considered as having a standard projected area ratio equal to the actual one, while the standard form slightly less than that coinciding with the outer half of bulbous-ended, narrow-rooted blades should be used.

Furthermore, should the final tip speed of the propeller or the indicated thrust per square inch of disc area exceed by any appreciable amount the tip speed or the $I.T._D$ (as modified by the thrust deduction factor C), given by Fig. 10 as the critical ones for the actual projected area ratio, cavitation will occur, the power will be increased above the estimate and the propellers will not run smoothly. The danger of cavitation with excess thrusts increases as the projected area ratio decreases, considerable safety existing with ratios of .4 and greater, the safety increasing with the projected area ratio.

Finally, all blades of abnormal form, narrow roots as compared with tips, narrow tips as compared with roots, and abnormal blade sections, should all be looked upon with suspicion and discarded as tending to vitiate results and possibly to lead to failure.

SOURCES OF ERRORS IN ESTIMATES OF PERFORMANCES.

These are many, and may be classed as follows:

1. Errors in estimate of effective horsepower: Caused by
   - *a.* Mistakes in percentage appendage resistance.
   - *b.* Variation in displacement from displacement at model-tank conditions.
   - *c.* Poor condition of ship's bottom.
   - *d.* Poor steering of vessel.
   - *e.* Adverse conditions of weather.
   - *f.* Adverse conditions of tidal flow.
   - *g.* Lack of depth of water on the trial course.

2. Errors of observation: Caused by
   a. Personal errors of observers.
   b. Errors of instruments.
3. Errors of computation: Caused by
   a. Errors in computing charts.
   b. Errors in exponents used in computing equations.
   c. Errors in estimate of standard block coefficient.
   d. Errors in estimate of standard projected area form where actual form varies widely from the standard.

The sources of error being so many, the analyzer should feel perfectly well satisfied with his work should the computed results of power fall within three (3) per cent. of the actual results attained for high-powered vessels and within five (5) per cent. for low powered ones, while the computed revolutions should fall within two (2) per cent. in all cases.

DATA REQUIRED AND FORM FOR COMPUTING.

The hull data required is the same as that necessary for use in the design of the propeller, while the propeller data must include pitch, diameter, actual projected area ratio, shape of projected area, sections of blades and diameter of propeller hub.

The preliminary computation is expressed in the following form, the problems all being solved as problems of reduced diameter:

(1) P = Pitch.
(2) D = Diameter.
(3) R = Assumed revolutions.
(4) $t.s. = R \pi D$.
(5) T.S. $\overline{>}$ $t.s.$
(6) A = $t.s. \div$ T.S.
(7) A^4.
(8) A^8.
(9) P.A. $\div$ D.A. = chart projected area ratios corresponding to T.S.

(10) $p.a. \div d.a. = (\text{P.A.} \div \text{D.A.}) \div \text{A}^4 =$ projected area ratio of reduced diameter propeller.

(11) $\text{I.T.}_\text{D} =$ Indicated thrust per square inch of disc area for P.A. ÷ D.A. (from charts).

(12) $\text{P.T.}_\text{p} =$ Propulsive thrust per square inch of projected area for P.A. ÷ D.A. (from charts).

(13) $\text{E.T.}_\text{p} =$ Effective thrust per square inch of projected area for P.A. ÷ D.A. (from charts).

(14) $1 - \text{S} = \text{P.T.} \div \text{E.T.}_\text{p}$.

(15) S = Apparent slip of propeller of P.A. ÷ D.A. ratio.

(16) $s = \text{S} \div \text{A}^8 =$ Apparent slip of propeller, $p.a. \div d.a.$ ratio.

(17) $1 - s$.

(18) $\text{P} \times \text{R}$.

(19) $101.33v = \text{P} \times \text{R} \times (1 - s)$.

(20) $v = \text{P} \times \text{R} \times (1 - s) \div 101.33$.

(21) $\left(\frac{1 - s}{1 - \text{S}}\right)^3 =$ Corrective factor for effective horsepower.

(22) C = Thrust deduction factor from chart 7 and from Fig. 2, this article.

(23) N = Number of propellers working under identical conditions.

(24) $\text{N} \times \text{IHP} = \frac{\text{N} \times \text{D}^2 \times \text{P} \times \text{R} \times \text{I.T}_\text{D}}{291.8 \times \text{C}^2 \times \text{A}^4} =$ Total indicated horsepower required under chart conditions for N propellers of $p.a. \div d.a.$ ratio at a speed v and revolutions R.

(25) P.C. = Propulsive coefficient for P.A. ÷ D.A. (from charts).

(26) $\text{E.H.P.} = \text{N} \times \text{IHP} \times \text{P.C.} =$ Gross effective horsepower.

(27) $\text{T.E.H.P.} = \text{E.H.P.} \div \text{C} =$ Thrust effective horsepower.

(28) $\text{D.E.H.P.} = \text{T.E.H.P.} \times \left(\frac{1 - s}{1 - \text{S}}\right)^3 =$ Net effective horsepower delivered under chart conditions at a speed v and revolutions R.

The above form is for three-bladed propellers only. Should the propeller be four-bladed, the actual final projected area ratio becomes $4/3 \times (10)$, and (24) becomes $(24) \div .865$, while for a two-bladed one, the projected area ratio becomes $2/3 \times (10)$ and (24) becomes $.75 \times (24)$.

Having made the computations, as above, for several values of T.S., none of them being less than *t.s.*, a series of curves of v, D.E.H.P. and IHP are laid down, using the values *p.a.* $\div$ *d.a.* as abscissas.

From these curves the values of v, D.E.H.P. and IHP, corresponding to the standard projected area form of the propeller blades in question, are taken and inserted in the following equations:

$$\text{IHP}_d = \text{IHP} \times \left(\frac{v_d^3}{v^3}\right)^{1-x} \times \left(\frac{d.e.h.p.}{\text{D.E.H.P.}}\right)^x. \tag{29}$$

$$R_d = R\sqrt[y]{\frac{\text{IHP}_d}{\text{IHP}} \times \frac{v_d}{v}}; \text{ where} \tag{30}$$

v_d = designed speed,

d.e.h.p. = tow-rope horsepower (all appendages), for v_d,

IHP_d = indicated horsepower for speed v_d,

R_d = revolutions for speed v_d.

Should it be desired to change the pitch so that the new pitch will equal rP, the new projected area ratio can be found by entering chart 8 with the constant developed area ratio and taking out the projected area ratio corresponding to the value of $\frac{r\text{P}}{\text{D}}$.

Entering the curves of v, D.E.H.P. and IHP with this new value of *p.a.* $\div$ *d.a.*, new values of these data are obtained. Equations (29) and (30) then become

$$\text{IHP}_d = r\text{IHP} \times \left(\frac{v_d^3}{rv^3}\right)^{1-x} \times \left(\frac{d.e.h.p.}{r\text{D.E.H.P.}}\right)^x. \tag{31}$$

$$R_d = R\sqrt[y]{\frac{\text{IHP}_d}{r\text{IHP}} \times \frac{v_d}{rv}}. \tag{32}$$

Should the tip speed corresponding to R_a be greater than the tip speed given by Fig. 10 for the actual projected area of a three-bladed screw, 3/4 of the total area for a four and 2/3 this area for a two-bladed one, there is danger of cavitation setting in with its accompanying vibrations and loss in efficiency of propulsion, and this danger increases as the pitch ratio $\frac{P}{D}$, for any given condition, increases, propellers of high pitch and low projected area ratios entering the cavitating range much earlier than those of low pitch and high projected ratios.

SHIPS HAVING MORE THAN TWO PROPELLERS.

Where vessels are fitted with more than two propellers on two shafts, it becomes necessary to analyze for each set of conditions separately and add the IHP_a's together for the total final IHP_a, and obtain the mean of the revolutions for the estimated mean revolutions.

Thus, for a vessel having three propellers on three shafts, the two wing propellers are calculated together, and the center propeller alone. For a four-shaft vessel, the two wing propellers are taken together and then the two inner ones.

The method of procedure to be followed, after the preliminary calculations of IHP, D.E.H.P. and v have been made, is as follows:

$D.E.H.P._{.1} = D.E.H.P. \times \frac{\overline{v_a}^3}{v^3}$. (Find for each condition).

$\lesssim D.E.H.P._{.1}$ = Sum of $D.E.H.P._{.1}$ for all conditions.

$\% = \frac{D.E.H.P._{.1}}{\lesssim D.E.H.P._{.1}}$ = percentage of driving effective horsepower delivered by propellers of each condition at a speed v_a, and under chart conditions of resistance.

$\lesssim d.e.h.p.$ = Total driving effective horsepower actually required by the vessel at the speed v_a.

$d.e.h.p. = \% \times \lesssim d.e.h.p.$ = driving effective horsepower which must be delivered at the speed v_a by the propellers of each condition.

Having obtained these values of *d.e.h.p.*,

$$IHP_d = IHP \times \left(\frac{v_d^3}{v^3}\right)^{1-x} \times \left(\frac{d.e.h.p.}{D.E.H.P.}\right)^x;$$

$$R = R \sqrt[y]{\frac{IHP_d}{IHP} \times \frac{v_d}{v}}, \text{ and}$$

$\lesssim IHP_d$ = the sum of the condition values of IHP_d.

$\frac{\lesssim R_d}{N}$ = Mean estimated revolutions for all propellers

$= \frac{2 \times \text{revs. of wing} + \text{revs. of center}}{3}$ for a three-shaft arrangement

$= \frac{\text{Revs. of outer} + \text{revs. of inner}}{2}$ for a four-shaft arrangement.

DOUBLE-ENDED VESSEL WITH TWO PROPELLERS, ONE LOCATED AT EACH END.

In forecasting the propeller performance of such a vessel, the after propeller only should be considered, and after the results have been obtained for it, the necessary corrective factors for the forward propeller and for the total be applied.

Having obtained the chart condition IHP, D.E.H.P. and v for the after propeller, proceed as follows:

d.e.h.p. = total driving effective horsepower required by the vessel for the designed speed v_d;

.65 *d.e.h.p.* = driving effective horsepower delivered by after propeller;

IHP_d = total indicated horsepower delivered by the engine to both propellers;

.60 IHP_d = indicated horsepower absorbed by after propeller;

$$.60\ IHP_d = IHP \times \left(\frac{v_d^3}{v^3}\right)^{1-x} \times \left(\frac{.65\ d.e.h.p.}{D.E.H.P.}\right)^x;$$

$$IHP_d = \frac{IHP}{.60} \times \left(\frac{v_d^3}{v^3}\right)^{1-x} \times \left(\frac{.65\ d.e.h.p.}{D.E.H.P.}\right)^x;$$

$$R_d = R \sqrt[y]{\frac{.60\ IHP_d}{IHP} \times \frac{v_d}{v}}.$$

Should the final power result, in all the above, be desired in shaft horsepower, the resultant values of IHPa should be multiplied by .92.

Should the mechanical efficiency of the reciprocating engines be estimated at less than 92%, the final estimated value of the power required will be $\frac{\text{IHPa} \times 92}{\%}$, where % is the estimated mechanical efficiency of the engine.

BLADE SECTIONS AND TIP SPEEDS.

Before going into the analysis of the probable performance of any propeller, as determined from its pitch, diameter and projected area ratio, the blade section should be examined, and if the blade section is of any of the forms shown on Fig. 3, with the exception of those marked *Creole* and *D.* it can be accepted as practically standard. The section marked *F.* will allow the propeller to turn up slightly faster than the estimated revolutions, while if exaggerated to the extent of an even division of the blade thickness on each side of the pitch plane, the revolutions will be considerably higher than those estimated. Should the form marked *D.* be the one submitted it should, unless very thin as compared with its width, be criticised as tending to waste of power due to increased resistance of blade to motion through the water. Should the form marked *Creole* be the existing one, it should be disapproved, unless that blade is very thin, as tending to produce earlier cavitation due to eddying of the water around the blade.

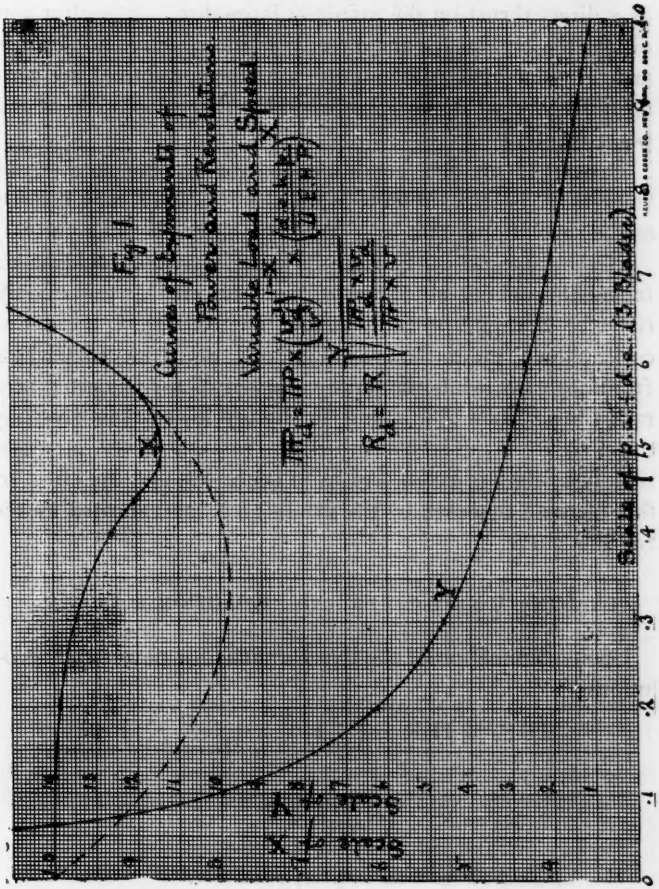
Should the tip speeds at the estimated revolutions exceed to any appreciable extent those given by Fig. 10 for the estimated corresponding standard projected area form, particularly for values of *p.a.* ÷ *d.a.* below .4, early cavitation may be expected, and the designer of the propeller be so notified.

For values of *p.a.* ÷ *d.a.* above .3, the tip speeds of Chart 5 may be exceeded until tip speeds from Fig. 10 corresponding to the I.T.D's of the points of tangency of the propulsive coefficient curves for the *p.a.* ÷ *d.a.* under consideration, with the enveloping curve shown on Chart 3 are reached. Beyond

these points of tangency the cavitating condition is rapidly entered.

CURVES OF X AND Y, EXPONENTS OF POWER AND OF REVOLUTIONS. (FIG. 1.)

The curves of X and Y and the final equations for IHP_a and R_a have been developed after many months' work and are the results obtained from the analysis of the actual performances of many vessels, some few of which are given in Table 1.



The forms of the curves shown agree very closely with the author's conception of propeller performances as modified in passing from the initial condition of infinite diameter and pitch with zero tip speed and finite projected area to the final condition of finite diameter, projected area ratio of unity, variable tip speed, zero pitch, and infinite slip.

In the initial condition, the apparent slip of the propeller is zero, the revolutions are zero, and the entire power of the engine, as modified by its mechanical efficiency, is delivered as a direct thrust on the infinitely large disc. In such a condition, the IHP will vary directly as the effective horsepower and the value of X will be unity. As the revolutions are zero, no difference what the value of IHP, the value of Y at this point is infinity.

Passing to the final condition, that of a complete disc, the value of X becomes infinite while the IHP will vary directly as the revolutions; that is, Y at this point has become unity.

If the same ratio of blade thickness to width could be retained throughout all values of the projected area ratio, the curve of X would probably follow, approximately, the dotted curve shown, the minimum value of X, occurring somewhere from .3 to .35, while the finite values of Y for projected area ratios lower than .58, would be slightly lower than given by the curve of Y. The blade-thickness ratio, however, increases rapidly as the projected area ratio decreases, and the effect of this increase is shown by the values of X, as indicated by the full line curve.

EXAMINATION OF POWER AND REVOLUTION FORMULAS.

Upon examination of the two formulas for power and revolutions,

$$\mathrm{IHP}_d = \mathrm{IHP} \times \left(\frac{v_d^3}{v^3}\right)^{1-X} \times \left(\frac{d.e.h.p.}{\mathrm{D.E.H.P.}}\right)^X;$$

$$\mathrm{R}_d = \mathrm{R} \times \sqrt[Y]{\frac{\mathrm{IHP}_d}{\mathrm{IHP}}} \times \frac{v_d}{v},$$

the first is seen to contain two controlling factors, of which the first, $\left(\frac{v_d^3}{v^3}\right)^{1-X}$ may be called the speed factor, and the second, $\left(\frac{d.e.h.p.}{\text{D.E.H.P.}}\right)^{X}$. the load factor.

As the value of X varies from unity to .87, reaching this minimum value at a projected area ratio of .5, it is readily

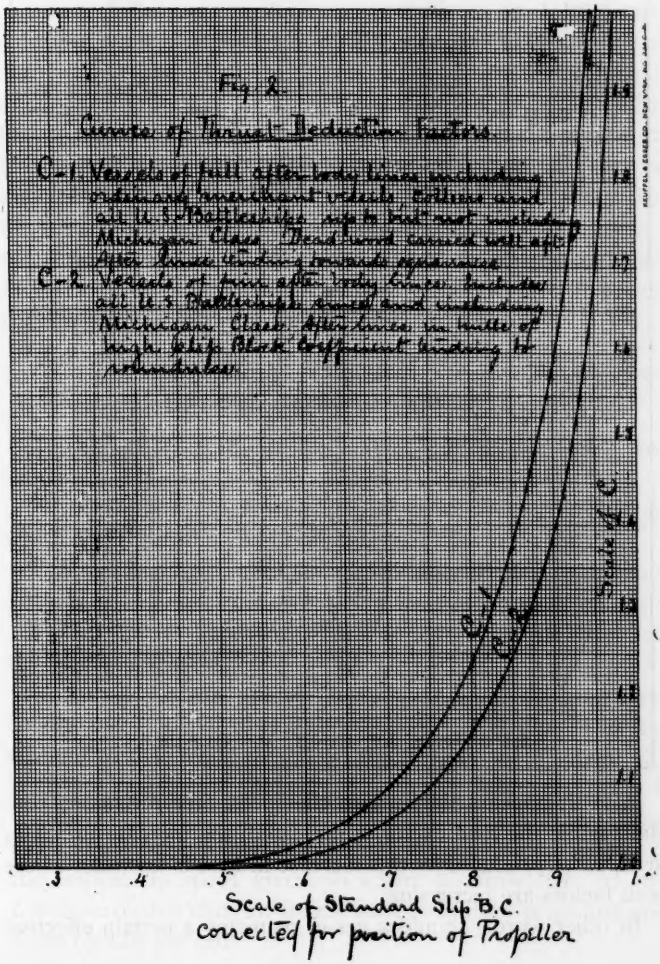


Fig. 2.
Curves of Thrust Reduction Factors.
C-1. Vessels of full after body lines including ordinary merchant vessels, colliers and all U.S. Battleships up to but not including Michigan Class. Twin screw vessels with aft after lines tending towards cruisers.
C-2. Vessels of fine after body lines including all U.S. Battleships, armed and unarmed Michigan Class. After lines in wake of high Block Coefficient tending to roundness.
Scale of C
.3
.4
.5
.6
.7
.8
.9
1.0
Scale of Standard Slip B.C.
Corrected for position of Propeller

seen that the effect of the load factor on indicated or shaft horsepower is very much greater than that of the speed factor, as the exponent of this latter factor varies from 0, for X = 1, to .39 = 3 (1 — .87), for X = .87.

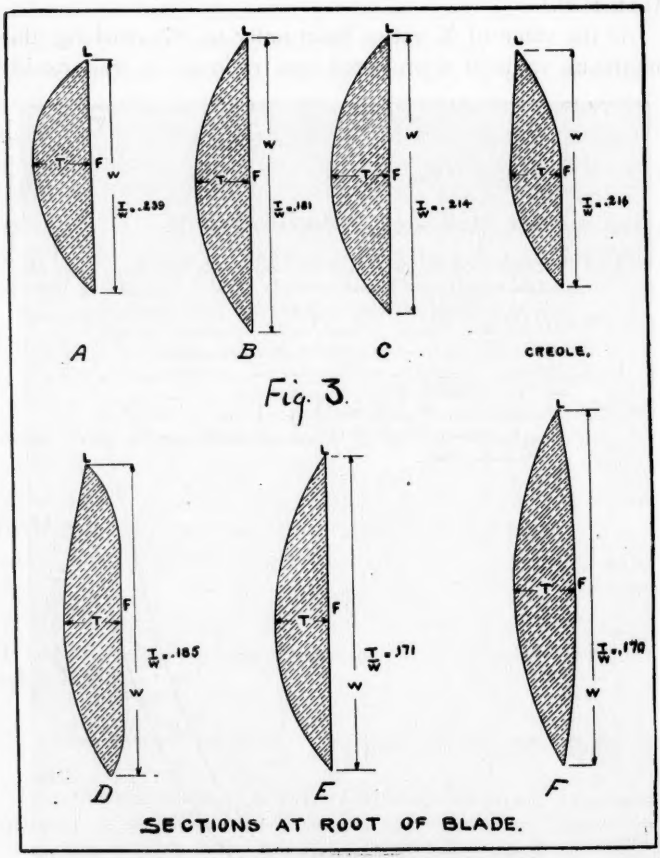


Fig. 3.

Also, it appears that where the speed factor remains constant while the load factor is increased, the increase in IHP_d or $S.H.P._d$ produced by this increase in load is less than where both factors are increasing.

In other words, should a vessel requiring a certain effective

horsepower for a speed v_a be loaded down so that an increased effective horsepower be required for this same speed, the increase in indicated or shaft horsepower will be less than would be required to deliver the increased effective horsepower at the speed corresponding to this effective horsepower under the original condition of loading.

It will further be noticed that, with speed factor remaining constant, the propulsive efficiency increases as the load factor increases, and this increase in efficiency probably continues until just before cavitation sets in, when the values of X and of Y change rapidly. This increase in efficiency indicated by the equation for power agrees with the model-tank results of Professor Flamm, who states that the maximum efficiency is realized just before cavitation occurs. This is not necessarily the case, however, where both speed and load factors are increasing as the gain in efficiency due to the increasing load factor may be more than overcome by the increase in power required by the growing speed factor.

CAVITATION PRODUCED BY EXCESSIVE TIP SPEEDS OF PROPELLERS. EFFECT ON X AND Y.

The curves Φ, multiplier for X, and λ, multiplier for Y, are shown on Fig. 4.

To obtain them, performances of vessels were required in which the following conditions existed:

1. After body of vessel sufficiently fine to insure minimum disturbance of water column in its flow to the propeller.

2. Tip speeds sufficiently high to minimize the effect of faulty blade sections.

Fortunately there are two vessels at hand meeting these conditions. One of them, the *Creole,* has a slip block coefficient of .54, while the other, the *G.,* has one of about .40. Both are twin-screw ships and the thrust deduction factor C is nearly, if not quite unity. The tip speed of the *G* propeller, at the point used, was nearly 29 per cent. in excess of the critical tip speed given on Chart 5, while that of the *Creole* exceeded that for its estimated standard projected area form by 116 per cent.

The curves of Φ and λ being based on three points only, one of these points being at the point of unity where the tip speed has 100 per cent. abscissa value, cannot be considered as more than approximations. They do, however, give a good idea of the changes that occur as cavitation increases.

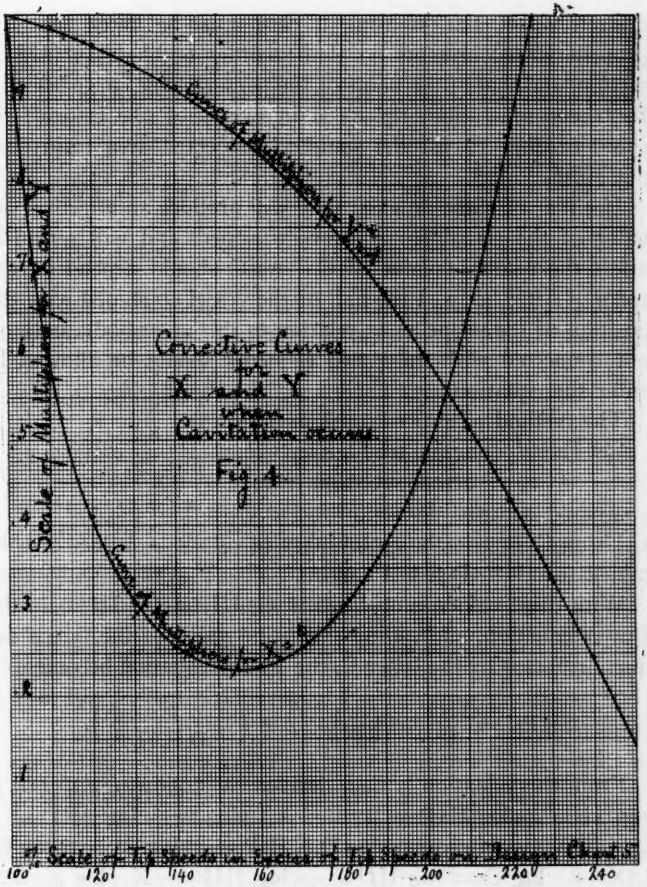
Taking the curve of λ; it is seen to fall slowly at first as the tip speed increases, the increment of fall increasing with the tip speed until this speed has reached approximately 2.6 times that given by the design Chart 5 for the projected area ratio of the propeller being considered. At this point $\lambda = 0$, and λY becomes zero.

Passing to the curve of Φ, a rapid fall in the value of Φ occurs until the tip speed has reached a value 50 per cent. greater than the critical speed, when it begins to rise, the rate of increase becoming greater as the tip speed continues rising, until the tip speed becomes 2.6 times the critical speed, at which point the value of Φ is infinity.

The exponents of the factors in the Power equation can be written 3 $(1 - \Phi X)$ and ΦX, and that in the Revolution equation λY. As Φ decreases, the weight of the speed factor in the Power equation increases while that of the load factor decreases until ΦX has reached its minimum value. After passing this point ΦX again increases, the weight of the speed factor begins to fall until 3 $(1 - \Phi X) = 0$, after which as Φ increases, the value of 3 $(1 - \Phi X)$ becomes negative and the fraction $\frac{\overline{v_a}^3}{v^3}$ inverts itself. As this is occurring with the speed factor, the load factor rapidly increases in weight until, at the limit of 2.6 the critical speed, it becomes infinity.

During these changes in the Power equation exponents, the value of λY has been falling, until when the limit of 2.6 the critical speed has been reached, the vessel has reached the maximum possible speed with the propellers fitted and any increase in revolutions results only in churning the water with absolutely no return in the way of an increase in effective horsepower delivered.

The curves are of practical value in cases where, on trials,



only revolutions and speed are obtained and where cavitation is occurring due to excessive tip speed. In such cases the Revolution equation can be utilized to obtain an approximation to the power which has been developed.

DETERMINATION OF THE THRUST DEDUCTION FACTOR C.

The Power equation gives a very ready and easy means of deriving the value of C (thrust deduction factor), for any

desired vessel, but in using it care must be taken that the propeller fitted presents no abnormalities of blade surface or section, and that at the point of the performance curve selected for the computation, tip speed in excess of the critical tip speed of Fig. 10 for the standard projected area ratio does not exist.

If either of these do exist they will produce an effect on the value of the actual horsepower developed, and will seriously affect the resultant value of C. As C should depend on the form of after body of the hull of the vessel combined with the position of the propeller in relation to this after body, nothing not connected with these two elements should be allowed to enter the equation.

The method of procedure is as follows:

Let IHP_d^1 = actual trial horsepower;

v_d = actual speed on trial.

Assume a thrust deduction factor C = 1.

Using C = 1 in the preliminary calculations, values are obtained for IHP, D.E.H.P. and *v*.

With these values, and substituting IHP_d^1 for IHP_d in the Power equation, and calling the actual value of the thrust deduction factor by the letter C, the Power equation becomes

$$IHP_d^1 = \frac{IHP}{C^2} \times \left(\frac{v_d^3}{v^3}\right)^{1-X} \times \left(\frac{C^3 \times d.e.h.p.}{D.E.H.P.}\right)^X.$$

From this equation is then derived the following:

$$\log IHP_d^1 = \log IHP + 3\,(1-X)\,(\log v_d - \log v).$$
$$+ X\,(\log d.e.h.p. - \log D.E.H.P. + 3 \log C) - 2 \log C.$$
$$(3X-2) \log C = \log IHP_d^1 - \log IHP - X\,(\log d.e.h.p. - \log D.E.H.P.)$$
$$- 3\,(1-X)\,(\log v_d - \log v).$$
$$\log C =$$
$$[\log IHP_d^1 - \log IHP - X\,(\log d.e.h.p. - \log D.E.H.P.)$$
$$- 3\,(1-X)\,(\log v_d - \log v)] \div (3X-2.)$$

The writer applied the above method to the propellers of the oil-fuel barges to which he has so frequently referred in his previous work, and the values of C obtained when the

propellers were in the original location was practically double that which existed after the position was lowered, thus crediting the major part of the improved performance to the change in position and the remaining small percentage to the increase in diameter of the successful screw over those of previous propellers.

ESTIMATE OF EFFECT OF ABNORMAL BLADE SECTION.

Calculate the values of IHP, v, D.E.H.P. and IHP$_a$ for v_a as before, and take the difference between IHP$_a$ and the actual power required for v_a. The difference may be credited to the blade section.

ILLUSTRATING PROBLEMS.

In choosing problems for the illustration of the foregoing methods of forecasting results care has been taken that a wide range in conditions shall be covered, and with this idea in view the following vessels have been used:

1. *E.* Battleship. Very fine after body. Twin screws. Thrust deduction factor = 1, even lower than given by curve C—2, Fig. 2, for the slip Block Coefficient of the vessel.

2. Steamship *Tyler.* Low-speed merchant vessel of ordinary form. Single screw. Thrust deduction factor falls on C—1, Fig. 2.

3. Chinese cruiser *Fei Hung* (now Greek cruiser *Helle*). Fine after-body lines. Three propellers on three separate shafts. Thrust deduction factor = 1. Propellers standard and alike.

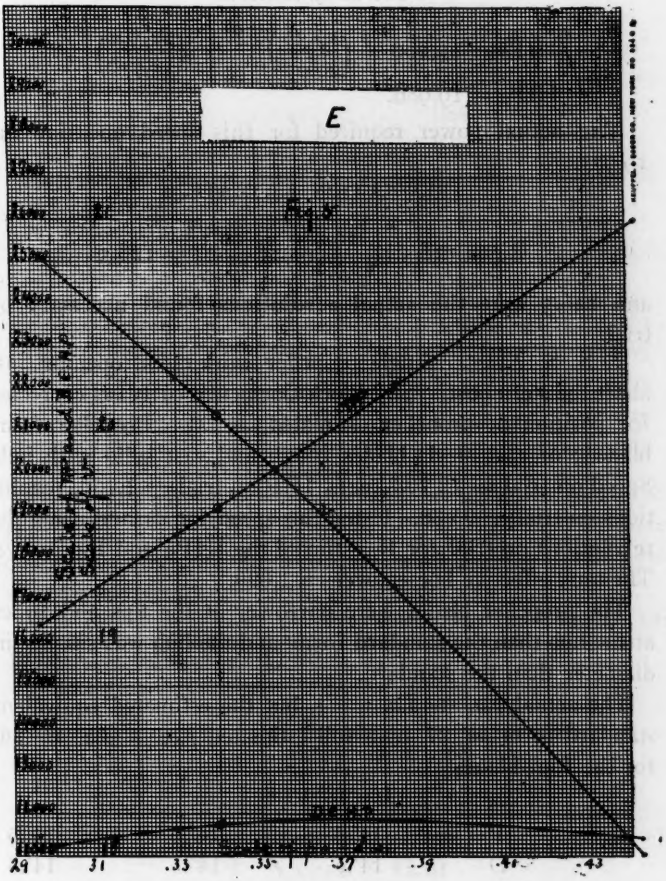
4. *H.* Fine after body. Four propellers on four separate shafts. Thrust deduction factor falls on curve C—2, Fig. 2. Propellers standard and alike.

5. Double-ended ferry boat *Mayor Gaynor.* Full ended, double-ended vessel. Two propellers on same shaft, one at each end of the vessel. Propellers standard in all respects and exactly alike.

SOLUTIONS.

1. *E.* Slip Block Coefficient = .662. Propellers three-bladed and practically standard in form. Diameter 16.5 feet. Pitch, 19 feet. Estimated revolutions R = 126.5, actual *p.a.* ÷ *d.a.* = .327, corresponding standard = .34. Required an estimate of the indicated horsepower necessary for a speed of 19.3 knots, the model-tank effective horsepower for this speed being 12,300. Use Chart 5.

P	19′	19′	19′	19′
D	16′.5	16′.5	16′.5	16′.5
R	126.5	126.5	126.5	126.5
t.s.	6,557	6,557	6,557	6,557
T.S.	6,557	6,700	6,900	7,100
log A.	0.00000	9.99064	9.97786	9.96545
log A^4	0.00000	9.96256	9.91144	9.86180
log A^8	0.00000	9.92512	9.82288	9.72360
P.A. ÷ D.A.	.296	.3025	.312	.322
p.a. ÷ *d.a.*	.296	.3297	.3826	.4427
$I.T._D$	3.66	3.80	4.0	4.22
$P.T._P$	8.4	8.49	8.6	8.7
$E.T._P$	9.56	9.68	9.83	9.97
1—S	.8786	.8770	.8748	.8726
S	.1214	.1230	.1252	.1274
s	.1214	.1461	.1878	.2408
1—*s*	.8786	.8539	.8122	.7592
log (P × R)	3.38084	3.38084	3.38084	3.38024
log 101.33 *v*	3.32463	3.31225	3.29050	3.26120
v	20.84	20.25	19.27	18.01
$\log \left(\frac{1-s}{1-S}\right)^3$	0.00000	9.96523	9.90325	9.81862
C	1	1	1	1
2 × IHP	16,414	18,576	21,997	26,016
P.C.	.6795	.677	.672	.6675
E.H.P.	11,154	12,576	14,782	17,366
T.E.H.P.	11,154	12,576	14,782	17,366
D.E.H.P.	11,154	11,609	11,830	11,436



Using the values of *p.a.* ÷ *d.a.* as abscissas, lay down curves of IHP, D.E.H.P. and *v*, as shown on Fig. 5.

The values of IHP, D.E.H.P. and *v* corresponding to a value of .34 for *p.a.* ÷ *d.a.* are found to be 19,200, 11,750 and 20.07, and these values are then substituted in the Power equation. From Fig. 1, the values of X and Y for *p.a.* ÷ *d.a.* = .34 are seen to be .96 and 4.12.

POWER ESTIMATE.

$$IHP_d = 19{,}200 \times \left(\frac{\overline{19.3^3}}{20.07^3}\right)^{1-.96} \times \left(\frac{12{,}300}{11{,}750}\right)^{.96};$$

$$IHP_d = 19{,}986.$$

The actual power required for this speed on trial was 19,975.

REVOLUTION ESTIMATE.

$$R_d = 126.5 \sqrt[4.12]{\frac{19{,}986}{19{,}200}} \times \frac{19.3}{20.07} = 126.5$$

and 126.5 were the actual revolutions found necessary on trial.

S. S. *Tyler*. Single propeller working in opening just abaft the stern post. Slip Block Coefficient of vessel corrected for position of propeller estimated = .71. Propeller four-bladed; of cast steel; blades rough and cast solid with hub. Speed on trial = 12.793 knots, IHP on trial = 1,750, revolutions on trial = 95.38. Using this speed for v_a and using the revolutions on trial for R, estimate the IHP_d and R_d for v_a. The tank effective horsepower = 1,090.

The propeller blades were narrower at the tips and fuller at the hub than the standard form, and the hub was smaller in diameter than the standard.

The actual *p.a.* ÷ *d.a.* = .4, but the estimated equivalent standard form = .27, or a full estimated *p.a.* ÷ *d.a.* = .36, for the four blades.

Use Chart 6.

P	14′.5	14′.5	14′.5
D	14′.5	14′.5	14′.5
R	95.38	95.38	95.38
t.s.	4,345	4,345	4,345
T.S.	4,345	4,500	4,700
log A	0.00000	9.98478	9,96589
log A^4	0.00000	9.93912	9.86356
log A^8	0.00000	9.87824	9.72712
P.A. ÷ D.A.	.241	.248	.256
4/3 *p.a.* ÷ *d.a.*	.321	.3804	.4673
$I.T._D$	1.92	2	2.07

P.T.$_P$	5.53	5.58	5.62
E.T.$_P$	5.9	5.96	6.01
1—S	.9373	.9363	.9351
S	.0627	.0637	.0649
s	.0627	.0843	.1217
1—s	.9373	.9157	.8783
log (P × R)	3.14083	3.14083	3.14083
v	12.79	12.5	11.99
$\log \left(\frac{1-s}{1-S}\right)^3$	0.00000	9.97129	9.91834
C	1.115	1.115	1.115
IHP	1,779	2,132	2,626
P.C.	.701	.70	.6999
E.H.P.	1,247	1,493	1,838
T.E.H.P.	1,119	1,339	1,648
D.E.H.P.	1,119	1,253	1,366

Using 4/3 *p.a.* ÷ *d.a.* as abscissas, laying down curves of IHP, D.E.H.P. and v as shown on Fig. 6, the values of these quantities corresponding to a four-bladed projected area ratio of .36 are found to be 2,012, 1,212 and 12.61.

The values of X and Y corresponding to the 3-blade projected area ratio, .27, are found to be .982 and 5.22.

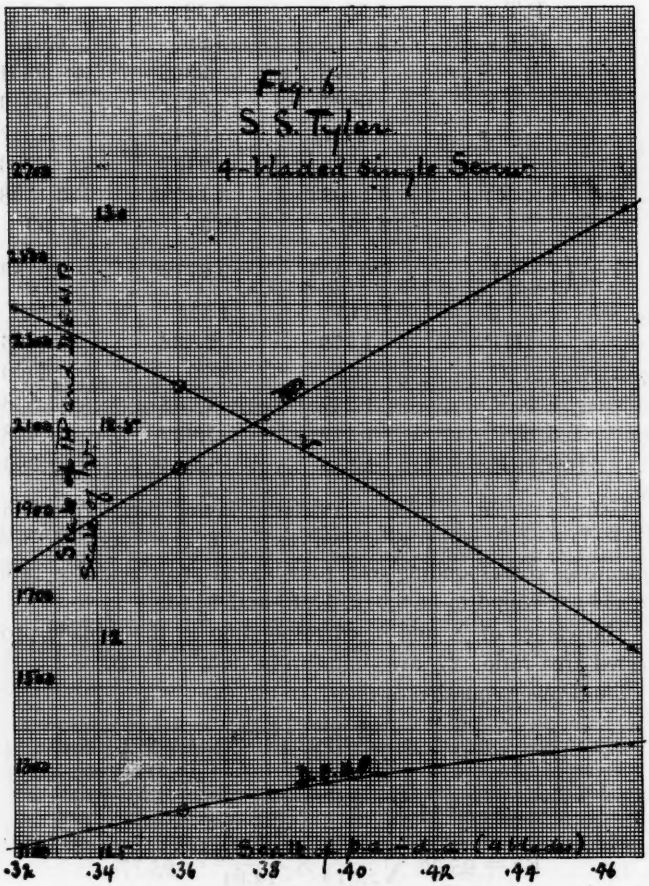
The Power equation is then,

$$IHP_d = 2{,}012 \times \left(\frac{12.793^3}{12.61^3}\right)^{1-.982} \times \left(\frac{1{,}090}{1{,}212}\right)^{.982}$$

$$IHP_d = 1{,}814\,;$$

$$R_d = 95.38 \sqrt[5.22]{\frac{1{,}814}{2{,}012} \times \frac{12.793}{12.61}} = 93.77.$$

In this case the estimated thrust deduction factor is slightly too large while the slip block coefficient is estimated slightly fuller than it actually is. This can be seen from the Revolution equation. The result of lowering the thrust deduction factor would be a decrease in IHP, and in IHP$_d$, while to increase the block coefficient would increase v, decreasing the value of the speed factor in both the Power and Revolution equations.



3. Chinese Cruiser *Fei Hung.* This vessel was designed for a speed of 20 knots, with the turbines developing about 7,000 S.H.P. at 525 revolutions. The standard Slip Block Coefficient for the wing propellers is estimated as .45 and, as corrected for the position of the center screw, at .525. The thrust deduction factor C, from Fig. 2 = 1. The propellers were of manganese bronze, were machined to pitch and polished. They were three-bladed and were all similar except

that the port propeller was left-handed, the other two being right-handed. The projected area form was standard, and = .50. Estimate S.H.P.a, *d.e.h.p.* and revolutions of wing and of center propellers at the designed speed, the total effective horsepower for this speed, called $\lesssim d.e.h.p.$, being 3,575, from the model tank curves.

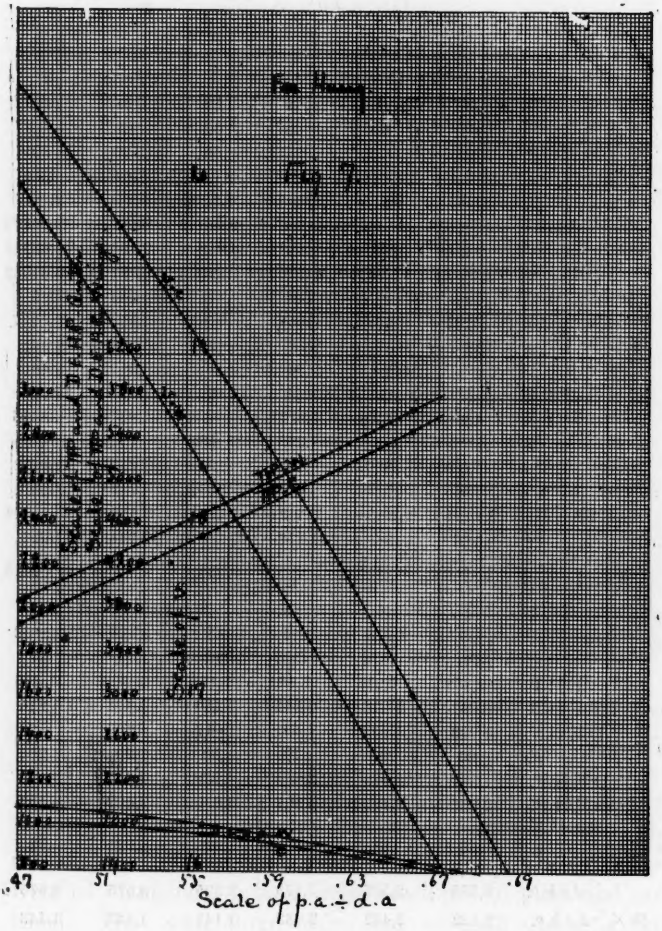
Use Chart 5.

SOLUTION.

	Wing.			*Center.*		
P	62″	62″	62″	62″	62″	62″
D	66″	66″	66″	66″	66″	66″
R	500	500	500	500	500	500
t.s.	8,640	8,640	8,640	8,640	8,640	8,640
T.S.	8,900	9,200	9,500	8,200	9,200	9,500
log A	9.98712	9.97272	9.95879	9.98712	9.97272	9.95879
log A^4	9,94848	9.89088	9.83516	9.94848	9.89088	9.83516
log A^8	9.89696	9.78176	9.67032	9.89696	9.78176	9.67032
P.A. ÷ D.A.	.418	.434	.45	.418	.434	.45
p.a. ÷ *d.a.*	.4707	.558	.6577	.4707	.558	.6577
I.T.D	6.45	6.85	7.28	6.45	6.85	7.28
$P.T._p$	9.4	9.5	9.56	9.4	9.5	9.56
$E.T._p$	11.33	11.44	11.55	11.10	11.21	11.32
1–S	.8296	.8304	.8277	.8468	.8474	.8445
S	.1704	.1696.	.1723	.1532	.1526	.1555
s	.2160	.2803	.3681	.1942	.2522	.3322
1–*s*	.7840	.7197	.6319	.8058	.7478	.6678
log (P × R)	3.41214	3.41214	3.41214	3.41214	3.41214	3.41214
v	19.986	18.346	16.317	20.541	19.063	17.024
$\log \left(\frac{1-s}{1-S}\right)^3$	9.92635	9.81358	9.63535	9.93535	9.83710	9.69415
C	1	1	1	1	1	1
IHP	3,889	4,716	5,699	1,945	2,358	2,850
P.C.	.607	.597	.588	.607	.597	.588
E.H.P.	2,361	2,816	3,351	1,180	1,408	1,676
T.E.H.P.	2,361	2,816	3,351	1,180	1,408	1,676
D.E.H.P.	1,993	1,833	1,491	1,017	968	828
v_d	20	20	20	20	20	20
D.E.H.P.a	1,997	2,375	2,854	939	1,117	1,343
$\lesssim$ D.E.H.P.a	2,936	3,492	4,197	2,936	3,492	4,197
$\% = \frac{\lesssim \text{D.E.H.P.a}}{\lesssim \text{D.E.H.P.a}}$	.68	.68	.68	.32	.32	.32
$\lesssim d.e.h.p.$	3,575	3,575	3,575	3,575	3,575	3,575
$\% \times \lesssim d.e.h.p.$	2,432	2,432	2,432	1,143	1,143	1,143

Laying down the curves of IHP, D.E.H.P. and v on *p.a.* ÷ *d.a.* as abscissas, the values to use in the Power and Revolution equations are found to be as follows:

	IHP	D.E.H.P.	v
Wing propellers	4,180	1,960	19.35
Center propeller	2,080	1,018	20.05



The Power equation for the wing screws is then

$$S.H.P._d = 4{,}180 \times .92 \times \left(\frac{\overline{20}^3}{\overline{19.35}^3}\right)^{1-.87} \times \left(\frac{2{,}432}{1{,}960}\right)^{.87}$$

$$S.H.P._d \text{ (wings)} = 4{,}700,$$

and the Revolution equation for the same propellers becomes

$$R_d = 500\sqrt[3.12]{\frac{4{,}700}{4{,}180 \times .92} \times \frac{20}{19.35}} = 538.9.$$

For the center propeller the Power equation is

$$S.H.P._d = 2{,}080 \times .92 \times \left(\frac{\overline{20}^3}{\overline{20.05}^3}\right)^{1-.87} \times \left(\frac{1{,}143}{1{,}018}\right)^{.87},$$

$$S.H.P._d = 2{,}114.$$

The Revolution equation is

$$R_d = 500\sqrt[3.12]{\frac{2{,}114}{2{,}080 \times .92} \times \frac{20}{20.05}} = 515.8.$$

The actual performance was

	S.H.P.$_d$	Revolutions.
Wing propellers, ...	4,700	535
Center propeller, ...	1,980	510
	6,680	526⅔

The estimated summation is

$$\lessgtr S.H.P._d = 6{,}814, \lessgtr \text{Revolutions} = 531.2.$$

While the estimated conditions for the wing propellers agree practically with the actual existing conditions, the estimate of Slip Block Coefficient for the center propeller is too low as indicated by the excess in S.H.P.$_d$ and in revolutions.

The result of increasing the Slip Block Coefficient estimate would be to raise the value of v, decrease the speed factor in both equations, and thus lower the computed values of S.H.P.$_d$ and of R_d.

4. *H.* This vessel is very fine aft, the thrust deduction

factor for the two outer propellers being unity, while that for the two inner ones has been taken from C–2, Fig. 2, as 1.01, the corresponding slip block coefficients being .595 and .625.

All four propellers are alike except as to direction of turning, the starboard propellers being right-handed and the port ones left-handed. The propellers are three-bladed, solid blades, machined to pitch and polished. The tabulated projected area ratio is .558, the estimated being .56. The blades are standard in form, so that the only difference between the estimated and the actual projected area ratios is caused by the difference in hub diameters.

Estimate the S.H.P. required by the Outer and by the Inner propellers, the effective horsepower delivered by each pair, and the average revolutions of each pair, also the total shaft horsepower and average revolutions of all propellers at a speed of 21 knots, the total effective horsepower for this speed being 15,650.

Chart 5.

SOLUTION.

	Outer.			*Inner.*		
P	102″	102″	102″	102″	102″	102″
D	110″	110″	110″	110″	110″	110″
R	400	400	400	400	400	400
t.s.	11,520	11,520	11,520	11,520	11,520	11,520
T.S.	11,520	11,650	11,800	11,520	11,650	11,800
log A	0.00000	9.99512	9.98957	0.00000	9.99512	9.98957
log A^s	0.00000	9.98048	9.95828	0.00000	9.98048	9.95828
log A^s	0.00000	9.96096	9.91656	0.00000	9.96096	9.91656
P.A. ÷ D.A.	.54	.546	.551	.54	.546	.551
p.a. ÷ *d.a.*	.54	.5711	.6066	.54	.5711	.6066
I.T.D	9.95	10.12	10.3	9.95	10.12	10.3
P.T.P	9.9	9.92	9.94	9.9	9.92	9.94
E.T.P	12.07	12.13	12.19	11.98	12.04	12.08
1–S	.8202	.8193	.8154	.8264	.8239	.8213
S	.1798	.1807	.1846	.1736	.1761	.1787
s	.1798	.1977	.2237	.1736	.1927	.2166
1–*s*	.8202	.8023	.7763	.8264	.8073	.7834
log (P × R)	3.53199	3.53199	3.53199	3.53199	3.53199	3.53199
v	27.554	26.952	26.078	27.761	27.12	26.317
$\log \left(\frac{1-s}{1-S}\right)^3$	0.00000	9.97267	9.93592	0.00000	9.97348	9.93838
C	1.00	1.00	1.00	1.01	1.01	1.01

	Outer.			*Inner.*		
IHP	18,803	20,004	21,427	18,433	19,610	21,005
P.C.	.5375	.5348	.532	.5375	.5348	.532
E.H.P.	10,107	10,618	11,405	9,908	10,485	11,175
T.E.H.P.	10,107	10,618	11,405	9,809	10,306	11,065
D.E.H.P.	10,107	10,045	9,840	9,809	9,766	9,601
v_d	21	21	21	21	21	21
D.E.H.P.$_d$	4,474	4,752	5,138	4,247	4,534	4,878
$\lesssim$D.E.H.P.$_d$	8,721	9,286	1,0016	8,721	9,286	10,016
$\% = \frac{\text{D.E.H.P.}_d}{\lesssim\text{D.E.H.P.}_d}$	.513	.513	.513	.487	.487	.487
$\lesssim d.e.h.p.$	15,650	15,650	15,650	15,650	15,650	15,650
$d.e.h.p.$	8,028	8,028	8,028	7,622	7,622	7,622

Plotting the above values of IHP, D.E.H.P. and v on $p.a. \div d.a.$ as abscissas, the values corresponding to a projected area ratio of .56 are seen to be

	IHP.	D.E.H.P.	v.
Outer	19,600	10,100	27.18
Inner	19,200	9,800	27.35

Referring to Fig. 1, the values of X and Y corresponding to a projected area ratio of .56 are seen to be X = .895, Y = 2.75.

The Power equations with the above values become:

For the Outer Propellers

$$\text{S.H.P.}_d = 19{,}600 \times .92 \times \left(\frac{\overline{21}^3}{\overline{27.18}^3}\right)^{1-.895} \times \left(\frac{8{,}028}{10{,}100}\right)^{.895};$$

$$\text{S.H.P.}_d = 13{,}525.$$

For the Inner Propellers

$$\text{S.H.P.}_d = 19{,}200 \times .92 \times \left(\frac{\overline{21}^3}{\overline{27.35}^3}\right)^{1-.895} \times \left(\frac{7{,}622}{9{,}800}\right)^{.895};$$

$$\text{S.H.P.}_d = 12{,}990;$$

$\lesssim$S.H.P.$_d$ = 26,515, the actual total shaft horsepower on trial being 26,300.

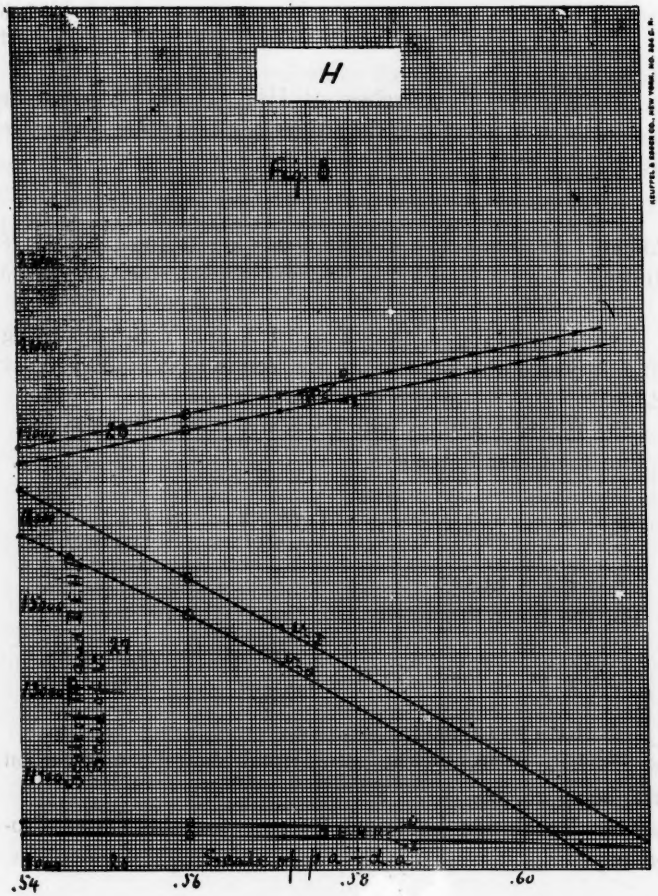
The Revolution equations become for the Outer Propellers,

$$R_d = 400\sqrt[2.75]{\frac{13{,}525}{19{,}600 \times .92} \times \frac{21}{27.18}} = 328$$

and for the Inner,

$$R_d = 400\sqrt[2.75]{\frac{12{,}990}{19{,}200 \times .92} \times \frac{21}{27.35}} = 325.$$

The actual revolutions were, for the outer propellers 326, and for the inner ones 318, the estimate of slip block coefficient for the inner screws being a little low. Correcting for



this would lower the revolutions and also the S.H.P.$_a$ for these propellers, and would bring the results even closer to the actual.

The estimated and actual results are

	Outer Propellers.		*Inner Propellers.*	
	Trial.	Estimate.	Trial.	Estimate.
Revolutions	326	328	318	325
S.H.P.$_a$.....	13,557	13,525	12,743	12,990

$\lesseqgtr$S.H.P.$_a$ Actual 26,300 and 26,515 Estimated.

5. Ferry-boat *Mayor Gaynor.* With this vessel a different type of problem is encountered. It may be stated as follows: "Given the speed, revolutions and indicated horsepower of a vessel on actual trial, find the slip block coefficient of the vessel and the indicated horsepower absorbed by and the effective horsepower delivered by the propeller in each location."

The vessel is of the type commonly known as "double-ended." There is one propelling engine, having a shaft reaching from end to end of the vessel, with a propeller fitted at each end. The propellers are alike, being cast from the same pattern; they are four-bladed, of cast steel, and the blades are cast solid with the hubs. The blade form is standard, as are also the blade sections, these latter being of the shape marked *C*, on Fig. 3. The actual projected area ratio of the four blades is .432, the corresponding standard 3-blade form being $\frac{3}{4} \times .432 = 324$.

The hull characteristics are:

Length between perpendiculars, feet.....	190
Beam at water line, feet.....	40
Draught, feet and inches.....	10–11¾
Coefficient immersed midship section.....	.773
Displacement in fresh water, tons.....	1,305
$\frac{\text{B.}}{\text{L.B.P.}}$	.21
Estimated slip block coefficient.....	.915
IHP on trial.....	1,845
Speed on trial, miles.....	14.662
Revolutions on trial.....	147.9

Chart 5.

SOLUTION.

After Propellers.

P	9′.55	9′.55	9′.55	9′.55	9′.55
D	10′.5	10′.5	10′.5	10′.5	10′.5
R	147.9	147.9	147.9	147.9	147.9
t.s.	4,879	4,879	4,879	4,879	4,879
T.S.	4,968	5,050	5,150	5,250	5,350
A	9.99215	9.98504	9.97652	9.96817	9.95998
A^4	9.96860	9.94016	9.90608	9.87268	9.83992
A^3	9.93720	9.88032	9.81216	9.74536	9.67984
P.A. ÷ D.A.	.229	.233	.237	.240	.244
4/3 *p.a.* ÷ *d.a.*	.3283	.3565	.3923	.4291	.4693
I.T.D	2.39	2.46	2.51	2.59	2.65
P.T.P	7.25	7.35	7.44	7.48	7.55
log (P × R)	3.14997	3.14997	3.14997	3.14997	3.14997
$v = v_a$	14.662	14.662	14.662	14.662	14.662
log 88v	3.11067	3.11067	3.11067	3.11067	3.11067
$1-s = \frac{88v}{P \times R}$	.9135	.9135	.9135	.9135	.9135
s	.0865	.0865	.0865	.0865	.0865
$S = s \times A^3$	.0749	.0657	.0561	.0481	.0414
1-S	.9251	.9343	.9439	.9519	.9586
$E.T.P = \frac{P.T.P}{1-S}$	7.84	7.87	7.88	7.86	7.88
*Slip B.C. for E.T.P	.85	.87	.895	.91	.92
$\left(\frac{1-s}{1-S}\right)^3$	9.98353	9.97063	9.95731	9.94633	9.93718
C for slip B.C.	1.20	1.30	1.375	1.43	1.48
IHP_d = IHP (4 blades)	1,101	1,031	1,017	1,048	1,079
P.C.	.698	.6979	.6977	.6975	.6974
E.H.P.	768	719	709	731	753
T.E.H.P.	640	553	516	511	508
d.e.h.p. = D.E.H.P.	616	517	468	452	440
≶ *d.e.h.p.*	700	700	700	700	700
≶ IHP	1,845	1,845	1,845	1,845	1,845
d.e.h.p. (Forward)	84	183	232	248	260
IHP_d (Forward)	744	814	828	797	766

Laying down the curves of IHP = IHP_d, D.E.H.P. = *d.e.h.p.*, and $v = v_a$ on the values of 4/3 *p.a.* ÷ *d.a.* as abscissas, Fig. 9, the values corresponding to a projected area

* Note.—From Chart 5.

ratio of .432, that of the actual 4-bladed propellers, are found to be IHP = IHPa = 1,050, D.E.H.P. = *d.e.h.p.* = 450, and calculated slip block coefficient = .911.

The estimated slip block coefficient by using Chart 1, was .915.

As the total IHPa on trial was 1,845, the forward propeller must have absorbed the difference between 1,845 and 1,050 or 795 IHP without correction for decreased mechanical efficiency of the engine due to its size and low power, and double length of shaft and number of line bearings, while it delivered the difference between the total effective horsepower, 700, estimated for the trial speed, and 450, that delivered by the after propeller, or 250 *d.e.h.p.*

Table of Results.

	IHP.	*d.e.h.p.*	$\frac{\text{IHP.}}{\Sigma\text{IHP.}}$	$\frac{d.e.h.p.}{\Sigma d.e.h.p.}$	$\frac{d.e.h.p.}{\text{IHP.}}$
After propeller	1,050	450	.569	.643	.4285
Forward propeller	795	250	.431	.357	.3144

Estimating the mechanical efficiency of the engine at 88 per cent. instead of 92 per cent., and correcting to a 92 per cent. basis, the IHP absorbed by the forward propeller becomes 715 and the total reduced power with the more efficient engine becomes 1,765.

The table then becomes:

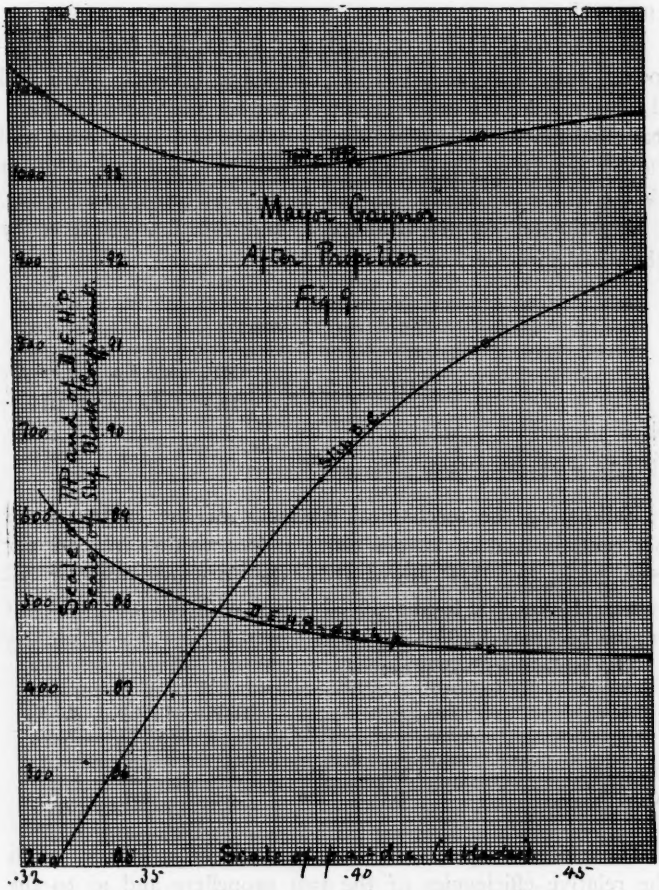
	IHP.	*d.e.h.p.*	$\frac{\text{IHP.}}{\Sigma\text{IHP.}}$	$\frac{d.e.h.p}{\Sigma d.e.h.p.}$	$\frac{d.e.h.p.}{\text{IHP.}}$
Forward	1,050	450	.595	.643	.4285
After	715	250	.405	.357	.3496

These results agree with the commonly accepted idea as to the relative efficiencies of the two propellers and as to the percentage of the total work which is done by each. They are perfectly consistent and can be shown to be so.

In the case of this vessel there is presented a ship identical

in all respects at the two ends, both being full-lined and fitted with stern post, rudder post and rudder.

Let it be supposed that, due to the fullness of the forward



lines, the water is banked up forward of the ship until the velocity in this preceding bank is equal to the velocity of the water in the wake.

The conditions in which the two propellers work are similar but exactly reversed.

The water enters the forward propeller with the same velocity that it enters the after one, and the velocities in the discharge columns are the same for the two screws.

Water in suction column to forward screw is in better and quieter condition than that of the after screw, as it is only obstructed by the rudder and rudder post, while that to the after screw is broken up by the full lines of the hull. Loss due to interference in suction column is less for the forward than for the after propeller.

These same causes of loss, but reversed, exist in the discharge columns of water.

The less disturbed condition of the water entering the forward propeller will tend to slow it down and also to increase its effective thrust, but the effect of its discharge column in impinging on the hull at an increased velocity will more than offset this gain.

Thrust deduction has been treated by the writer as being due to the form of hull and the position of the propeller in relation to the hull, the IHP for constant revolutions increasing as the thrust deduction decreases, with a rise in effective horsepower delivered.

With propellers alike in all respects, working in exactly the same conditions except as to thrust deduction, the following relations between IHP absorbed and effective horsepower delivered obtain:

$$\frac{\text{IHP}_1}{\text{IHP}_2} = \frac{\overline{C_2}^2}{\overline{C_1}^2} = r^2,$$

$$\frac{d.e.h.p._1}{d.e.h.p._2} = \frac{\overline{C_2}^3}{\overline{C_1}^3} = r^3,$$

where r is the inverse ratio of the existing thrust deduction values.

These proportions should hold in the case of the propellers of the *Gaynor* should the results obtained in the calculations be correct. That they do hold is shown by the following:

$$r^2 = \frac{\text{IHP (For'd)}}{\text{IHP (Aft)}} = \frac{1050}{715} = 1.468$$

$$r = 1.212$$

$$r^3 = \frac{d.e.h.p.\ \text{(For'd)}}{d.e.h.p.\ \text{(Aft)}} = \frac{450}{250} = 1.80$$

$$r = 1.216$$

and the two values of r so obtained are seen to be practically equal.

LOSS DUE TO THE TWO PROPELLERS OPERATING TOGETHER.

Trials of the double-ended ferry boats *Edgewater* and *Cincinnati* demonstrated that, with those two vessels it required less IHP for a given speed with only the after propeller in operation than it did with two.

The probable result, if such an experiment were tried on the *Gaynor,* can be directly obtained by the use of the Power equation:

After propeller, $\text{IHP}_d = 1{,}050 \times \left(\frac{700}{450}\right)^{.96} = 1{,}605$, or,

correcting for lower engine efficiency, $= 1{,}605 \times \frac{92}{88} = 1{,}678$,

and a gain of 1,845—1,678 = 167 IHP would be experienced.

The $\text{IHP}_d{}^1$ at the beginning of cavitation would be (as shown later),

$$= \frac{850}{.865C^2}\left\{ P \times D \times \left(\frac{p.a.}{d.a.}\ (3\ \text{blades})\right)^{2.82} \right\} = 2{,}008, \text{ and,}$$

therefore, no fear of cavitation should be felt with this propeller.

For the forward propeller,

$$\text{IHP}_d = 715 \times \left(\frac{700}{250}\right)^{.96} = 1{,}921 \text{ or,}$$

correcting for engine efficiency,

$1{,}921 \times \frac{92}{88} = 2{,}009$, a loss of 2,009 — 1,845 = 164 IHP.

The $\text{IHP}_d{}^1$ at the beginning of cavitation will be

$$= \frac{850}{.865C^2}\left\{ 9.55 \times 10.5 \times (.324)^{2.82} \right\} = 1{,}632,$$

C for the forward propeller being 1.586 and for the after one, 1.43, and in only the case of the forward screw may cavitation due to excessive tip speed or power be anticipated.

TABLE I.

In this table (Table I) are given the actual and the computed indicated or shaft horsepowers and the actual and the computed revolutions for the official trials of several vessels. There are also columns giving the ratios of computed to actual powers and revolutions.

The only vessels showing a difference of over 2½ per cent. in the estimate of power are the *C, Tyler, N,* and *B.* All of these cases can be accounted for.

1. *Tyler.*—Slip block coefficient used in computation was a little low. Thrust deduction factor slightly high.

2. *B.*—Highest reliable point on standardization curve at 18.95 knots, 16,200 IHP. Fair curve extended to higher speeds and powers. 18,300 IHP for 19.5 knots considered doubtful.

3. *N.*—Bad weather conditions and bad distribution of power in engine, producing great variation in torque at high powers tended to waste power.

4. *C.*—This vessel is a sister ship to the *J,* and her propellers were made from the same designs. The only difference that existed on trial, so far as known, was in the trim of the vessels. Naval Constructor Taylor determined, by a series of model tank experiments, that the effect of trim of a vessel on its resistance is so small as to be practically negligible, so the reason for the better performance of the *C* must be sought for in other directions.

The difference in the trim of the two vessels was about one foot, the *C* being about 3 feet by the stern.

The improvement may have been caused as follows:

As the vessel was gradually trimmed by the stern, the propellers were brought lower and lower in the water until, finally at some point of trim greater than that of the *J,* the water in the column moving to the propeller began to feel the influence

TABLE OF ACTUAL AND ESTIMATED PERFORMANCES.

Vessel.	Propeller.				Speed, knots.	I.H.P.$_d$ or S.H.P.$_d$ on trial.			Revolutions.			Remarks.
	D.	P.	$\frac{pa}{da}$	Standard form.		Actual.	Computed.	Computed / actual	Actual.	Computed.	Computed / actual	
E	16.5′	19′	.327	.34	19.3	19,975	19,968	.9996	126.5	126.5	1.000	Conditions normal.
C	17.25′	18′	.308	.32	18	14,980	15,698	1.047	114.5	119.7	1.054	Vessel trimmed by stern.
J	17.25′	18′	.308	.32	18	15,800	15,698	.9935	117.2	119.7	1.0213	Vessel trimmed by stern (less than min.)
K	17.25′	18′	.308	.32	18	15,700	15,698	.9998	119.0	119.7	1.006	Vessel trimmed slightly by stem.
A	17.75′	18′	.313	.35	18	16,480	16,301	.9891	114.5	116.77	1.0198	Broad tip blades.
F	17.75′	17.625′	.345	.33	18	15,500	15,805	1.0197	120.5	118.06	.9797	Narrow tip blades. Trim same as *N. H.*
L	18′	21.75′	.318	.32	22	25,500	25,110	.9847	121.6	122.16	1.0046	Slightly wide at tips. Bad section.
M	18′	21.75′	.310	.33	22	25,800	25,914	1.0044	120.2	122.38	1.018	Too little actual area. Very slight vibra.
N	18′	22.5′	.306	.328	22	27,100	25,847	.9537	119.0	120.4	1.0118	Too little actual proj. area. Cavitated.
Tyler	14.5′	14.5′	.4	.27	12.793	1,750	1,814	1.036	95.38	93.79	0.983	4-bladed propeller.
G	9.5′	8.67′	.520	.520	25	15,260	15,642	1.025	357	356.47	.9985	Conditions normal.
Fei Hung. wing	66″	62″	.500	.500	20	4,700	4,700	...	535	538.9	...	3 screws.
Fei Hung. cent'r						1,980	2,114	1.02	510	515.8	1.0087	
H outer	110″	102″	.548	.560	21	13,557	13,525	...	326	328.2	...	4 screws.
H inner						12,743	12,992	1.008	318	324.95	1.014	
O	92½″	80″	.600	.600	29.5	16,467*	16,858	1.0237	581*	574.33	.9885	* Mean of three vessels .8 p. ct. App. R.
B	17.54′	18′	.315	.320	19.5	18,300	19,013	1.037	125	125.65	1.0052	19.5 knots is beyond highest point of standardization curve.

of the decreased change in direction of flow required for it to reach its goal. The water in this column became less turbulent, and reached the propeller as a solid, quietly flowing stream. This quietness of flow would tend to slow down the propeller, decrease the thrust deduction factor and increase the thrust. If this actually occurred, the new value of C can be found from the Power curve.

Having obtained the value of IHPa in the calculations for the *J*, where

$$C = 1.06,$$

Let C^1 = Thrust deduction factor for $C = rC$.

IHPa = 15,698 for *J*,

IHPa = 14,980 for *C*,

$$\log r = \frac{\log 14{,}980 - \log 15{,}698}{3X - 2},$$

X from Fig. 1, for *p.a.* ÷ *d.a.* = .32 is .96,

$$\log r = 9.97690,$$

$$r = .9482,$$

$$C^1 = 1.06 \times .9482 = 1.0051.$$

The Revolution equation becomes

$$Ra = 120 \sqrt[4.2]{\frac{14{,}980 \times r^2 \times 18}{15{,}650 \times 18.26}}$$

where 15,650 and 18.26 are obtained in the preliminary computation = Ra = 115.4. That is, by trimming the vessel three feet by the stern the thrust deduction loss has been nearly, if not entirely, avoided.

LOSS DUE TO BAD BLADE SECTION.

The vessel chosen to illustrate this point is the *D*, a sister ship of the *C*, and whose origanal propellers were notorious (in the service) for their lack of propulsive efficiency.

The blade section at the hub is shown on Fig. 4. In order to assist in the bad showing made by this propeller, its other characteristics, that is, the combination of pitch, diameter and projected area, were so bad that its showing with a good section would have been far inferior to that of the propellers fitted to the other vessels of the class.

While the tabulated projected area ratio as given is .345, the actual standard form, on account of hub diameter, appears to be more nearly .37, this being probably a slight over estimate.

From the preliminary computations, using the same values of R = 120 revolutions, P being 17.5 feet and D 17.44 feet, the values of IHP, D.E.H.P. and v for a projected area ratio of .37, are found to be 18,150, 9,500 and 16.96.

The values of *d.e.h.p.* and v_a are 9,344 and 18.

Inserting these values in the Power equation, the value of X for .37 being .947, there results

$$IHP_a = 18{,}150 \times \left(\frac{\overline{18}^3}{\overline{16.96}^3}\right)^{1-.947} \times \left(\frac{9{,}344}{9{,}500}\right)^{.947}$$

$$IHP_a = 18{,}041,$$

$$R_a = 120\sqrt[4]{\frac{18{,}041}{18{,}150} \times \frac{18}{16.96}} = 121.6.$$

The actual revolutions on trial were 120.6, the difference between the actual and the estimated being caused by the over estimate of projected area ratio.

The actual IHP_a on trial was 19,000. Allowing an error of 2½ per cent. to exist due to errors in estimates and instruments, the actual IHP reduces to 19,000 × .975 = 18,525, and the loss due to the blade section shown on Fig. 3, and marked *D.* = 18,525 — 18,041 = 484, or a percentage increase in power of $\frac{484}{18{,}041} = 2.68$ per cent.

CAVITATION: TIP SPEEDS AND INDICATED THRUSTS PER SQUARE INCH OF DISC AREA AT POINTS WHERE CAVITATION COMMENCES FOR DIFFERENT VALUES OF PROJECTED AREA RATIO.

In considering this subject the writer prefers to divide Cavitation under two heads:

1. False Cavitation.
2. True Cavitation.

False Cavitation.—Under this head is placed cavitation due to faulty forms of blade section which cause eddying around the blade, forming cavities and causing more or less violent vibration accompanied by loss of power. This type of cavitation, when it occurs, starts with the first motion of rotation of the propeller, growing more and more violent as the speed of rotation increases. Its existence is independent of the thrusts but its violence increases with them.

True Cavitation.—Under this head is considered cavitation due to tip speeds of the propeller and the indicated thrusts required to produce these tip speeds. As the intensity of thrust depends upon the projected area ratio and as the tip speeds also depend upon the projected area ratio, it is assumed that there exists a constant relation between tip speed and projected area ratio and between indicated thrust per square inch of disc area, or per square inch of projected area, and the projected area ratio at the condition where cavitation begins, as at this point, in all cases, the head producing flow of water to the propeller becomes insufficient and the column of water on the suction side of the propeller commences to disrupt.

It should be noted, however, that the intensity of the thrusts at the point of cavitation depends also, upon the thrust deduction factor C, and is represented generally by the equation,

$$\text{Net Indicated Thrust} = \frac{\text{Chart Indicated Thrusts}}{C^2},$$

the values of $I.T._D$ and $I.T._P$ given by the Charts being those that exist when $C = 1$, or when the thrust deduction is *nil*.

The equation representing the relations existing between tip speed and projected area ratio and between indicated thrusts and projected area ratio at the "birth of cavitation" are of the following forms:

$$\overline{T.S.}^{n} = B \times \left(\frac{p.a.}{d.a.}\right)^{w}$$

$$\overline{I.T._D}^{x} = E \times \left(\frac{p.a.}{d.a.}\right)^{y},$$

in which B and E are unknown constants and u, w, x and y unknown exponents.

By referring to Chart 3 (writer's previous work), it will be noted that all of the propulsive coefficient curves become tangent at one part of their course to an enveloping curve. It has been assumed that at this point of tangency a critical point has been reached in the career of the propeller and that this critical point marks the beginning of cavitation, as, after touching this curve each curve of coefficients falls away, more or less rapidly, depending upon the projected area ratio. The smaller this ratio the more rapidly does the curve fall.

The values of T.S. and of I.T._D corresponding to these points of tangency were estimated to be

for .25 — 5,200 — 2.7,
.3 — 6,600 — 3.75,
.4 — 9,300 — 6.5,
.6 — 14,800 — 12.8,

the curves being considered to follow the enveloping curve closely through quite a range of thrusts before finally touching and falling away.

Substituting these values of T.S. and of $p.a. \div d.a.$ in the tip-speed equation and solving for w in terms of u, it was determined that

$$w = 1.12\ u \text{ (approximately)}.$$

Substituting again, and solving for B, using different values of u, the following equation resulted:

$$\overline{\text{T.S.}}^{.001} = 1.0102 \times \left(\frac{p.a.}{d.a.}\right)^{.00112},$$

which, for greater convenience, was put in the form

$$\text{T.S.} = 25{,}550 \times \left(\frac{p.a.}{d.a.}\right)^{1.12}.$$

The same method was used in obtaining the values of y in terms of x and of E, the following being the resultant equation:

$$\text{I.T.}_D = 30.5 \left(\frac{p.a.}{d.a.}\right)^{1.7}.$$

$$\text{I.T.}_P = 30.5 \left(\frac{p.a.}{d.a.}\right)^{.7}.$$

The results obtained by the use of these equations are shown plotted as full lines on Fig. 10, the curves of I.T.$_D$, and T.S. from Chart 5, being shown as dotted lines in order to show the leeway existing in design as a general guide for the exercise of judgment in deciding whether to design for overload conditions or for specified conditions. Thus, where propellers will fall between 0 and .35 projected area ratio the curves show that they are at the verge of cavitation at the design point. All other projected area ratios give considerable leeway before cavitation commences. If the possible overload condition is not much in excess of the specified conditions, propellers of from .0 to .35 projected area ratio may be designed for the specified conditions, as the vibration due to cavitation does not become serious for quite a distance beyond the "birth of cavitation," as for instance,

	I.T.$_D$	Standard Projected Area Ratio.	Vibration.
X	4.64	.33	Not noticeable.
M	4.7	.33	Considerable.
G	4.5	.32	Moderate.

These thrusts are approximately 10 per cent. in excess of those at the beginning of cavitation, and indicate that this excess may be imposed on the propeller without serious trouble being experienced.

In connection with Fig. 10, attention is called to an error in the tip-speed curve of Chart 5. The tip speeds beyond the projected area ratio, instead of curving up sharply, as given, should practically parallel the curve of I.T.$_D$.

An estimated curve of propulsive coefficients may also be obtained by deriving an equation for P.C., using the values

of $I.T._D$ and of T.S. for the different values of $p.a. \div d.a.$, as given on Fig. 10.

The equation is

$$P.C. = \frac{p.a.}{d.a.} \times \frac{1}{I.T._D} \times \sqrt[4]{T.S.} = \frac{\sqrt[4]{T.S.}}{I.T._P},$$

where $I.T._P$ = Indicated Thrust per square inch of Projected Area.

By substituting in these equations the value of T.S. and $I.T._D$ or $I.T._P$ as given on Fig. 10, in terms of $p.a. \div d.a.$, these equationss take the form

$$P.C. = \frac{\sqrt[4]{25,550}}{30.5\left(\frac{p.a.}{d.a.}\right)^{.42}}.$$

The resultant curve is shown plotted on Fig. 11 with the empirical Chart 3 enveloping curve superimposed on it.

The only wide divergence existing is seen to be at the very low values of $p.a. \div d.a.$, and as propellers of such primary ratios are found with full-bodied vessels only, the thrust deduction factor takes account of this difference and practically corrects for it.

GENERAL EQUATIONS.

The equations given for T.S., $I.T._D$, $I.T._P$ and P.C. in the foregoing, apply only to chart conditions and to a thrust deduction factor C = 1.

Should C have any other value, the new value of $I.T._D$ = $I.T._D$ (Fig. 10) $\div C^2$, the new value of $I.T._P$ = $I.T._P$ (Fig. 10) $\div C^2$, the new value of P.C. = P.C. (Fig. 11) $\div$ C and the equation take the following forms:

$$T.S. = 25,550\left(\frac{p.a.}{d.a.}\right)^{1.12} \quad \therefore R_d{}^1 = \frac{25,550}{\pi D}\left(\frac{p.a.}{d.a.}\right)^{1.12},$$

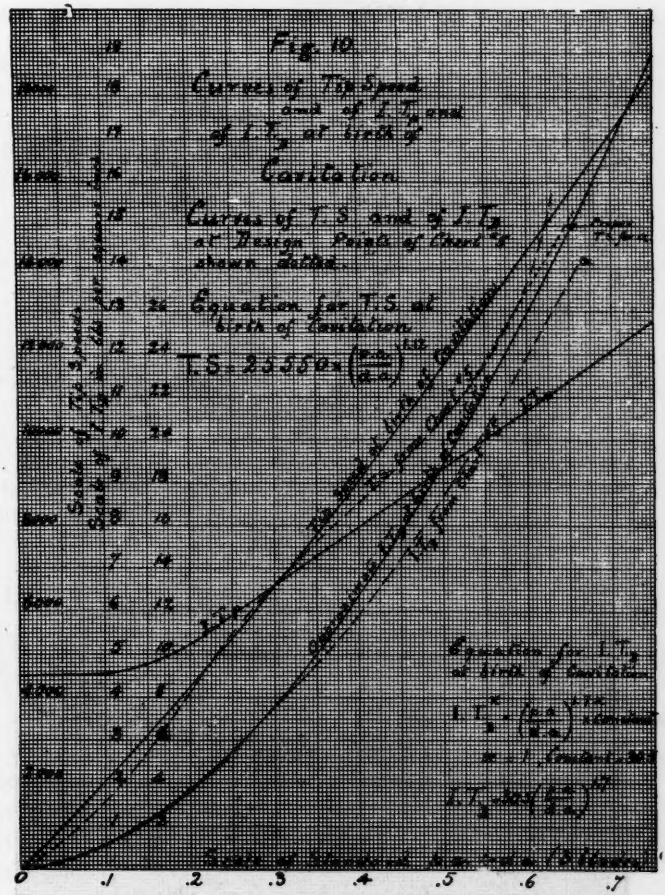
$$\text{New } I.T._D = \frac{I.T._D}{C^2} \text{ (Fig. 10)} = \frac{30.5}{C^2}\left(\frac{p.a.}{d.a.}\right)^{1.7},$$

$$\text{New I.T.}_P = \frac{\text{I.T.}_P}{C^2}\ (\text{Fig. 10}) = \frac{30.5}{C^2}\left(\frac{p.a.}{d.a.}\right)^{\cdot 7},$$

New P. C.

$$= \frac{\text{P.C.}}{C}\ (\text{Fig. 11}) = \frac{1}{C} \times \frac{p.a.}{d.a.} \times \frac{1}{\text{I.T.}_D\ (\text{Fig. 10})} \sqrt[4]{\text{T.S.}},$$

$$= \frac{\sqrt[4]{\text{T.S.}}}{C \times \text{I.T.}_P\ (\text{Fig. 10})} = \frac{\sqrt[4]{25{,}550}}{C \times 30.5\left(\frac{p.a.}{d.a.}\right)^{\cdot 42}}$$

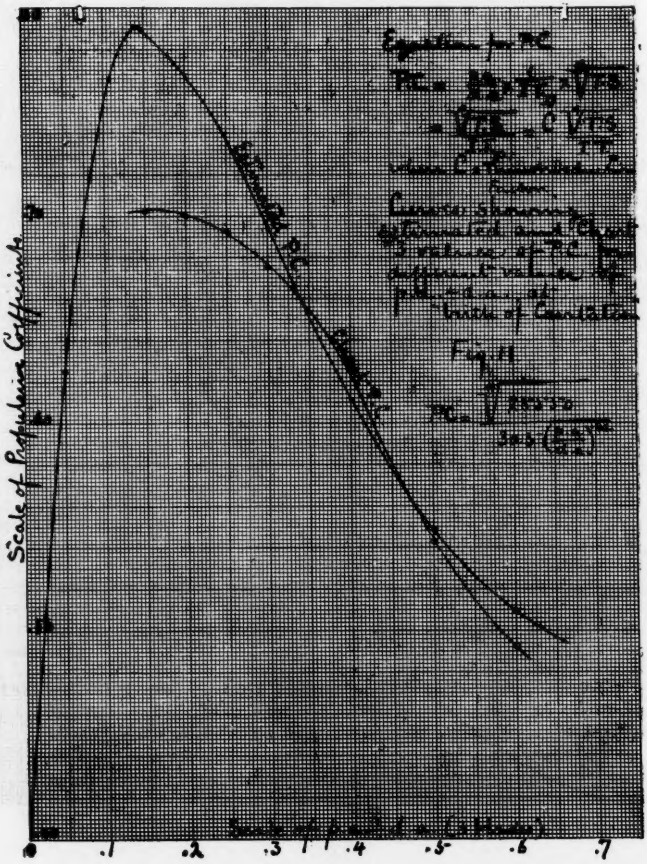


The above equations being for chart conditions as given by Figs. 10 and 11, and for these conditions as modified by the thrust deduction factor, it becomes necessary to devolve an equation which will fit the Power and the Revolution equations in which different conditions from the chart ones exist.

These equations, as already pointed out, are

$$\text{IHP}_d = \text{IHP} \times \left(\frac{v_d^3}{v^3}\right)^{1-X} \times \left(\frac{d.e.h.p.}{\text{D.E.H.P.}}\right)^{X} - \text{Power},$$

$$R_d = R \sqrt[Y]{\frac{\text{IHP}_d}{\text{IHP}} \times \frac{v_d}{v}} - \text{Revolution}.$$



The general equation for "birth of cavitation," containing all the factors entering into "true cavitation" is:

$$\text{T.S.} \times \text{I.T.}_{\text{D}} = 25{,}550 \times 30.5 \left(\frac{p.a.}{d.a.}\right)^{2.82},$$

or with thrust deduction factor C,

$$\frac{\text{T.S.} \times \text{I.T.}_{\text{D}}}{C^2} = \frac{25{,}550 \times 30.5}{C^2} \left(\frac{p.a.}{d.a.}\right)^{2.82}$$

or replacing $\frac{\text{I.T.}_{\text{D}}}{C^2}$ by the actual value of indicated thrust per square inch of disc area, and calling it $i.t._{\text{d}}$, then

$$\text{I.T.}_{\text{D}} = C^2 \times i.t._{\text{d}}$$

and the equation becomes

$$\text{T.S.} \times i.t._{\text{d}} \times C^2 = 25{,}550 \times 30.5 \left(\frac{p.a.}{d.a.}\right)^{2.82}$$

$$\text{or } (\text{T.S.} \times i.t._{\text{d}}) = \frac{779{,}300}{C^2} \left(\frac{p.a.}{d.a.}\right)^{2.82}.$$

T.S. being in this case, πDR_{d}^{1}, and $i.t._{\text{d}}$ being $(IHP_{\text{d}}^{1} \times 33{,}000) \div (P \times R_{\text{d}}^{1} \times \frac{1}{4}\pi D^2 \times 144)$, whence $IHP_{\text{d}}^{1} = \frac{850}{C^2} \times P \times D \times \left(\frac{p.a.}{d.a.}\right)^{2.82}$, "and this final equation is the general equation, for three-bladed propellers, to use in fixing the point where cavitation begins."

For four-bladed propellers the equation for IHP_{d}^{1} becomes $IHP_{\text{d}}^{1} = \frac{850}{.865C^2} \times P \times D \times \left(\frac{p.a.}{d.a.}\right)^{2.82}$, where $\frac{p.a.}{d.a.} = \frac{3}{4}$ total $\frac{p.a.}{d.a.}$ for four blades.

The equation is based on the assumption that for any particular projected area ratio the velocity of flow in the suction column of water going to the propeller plus the speed of advance of the propeller is directly dependent upon the tip speeds of the propeller and upon the indicated thrusts to which it is subjected to obtain these tip speeds.

EFFECT OF FORM OF AFTER-BODY LINES IN VESSELS WHERE THE PROPELLER IS WORKING IN HEAVY SLIP BLOCK COEFFICIENT CONDITIONS.

In order to illustrate the meaning of the following terms used on Fig. 2,

"After lines tending to squareness" and "After lines in hulls of high slip block coefficient tending to roundness," Figs. 12 and 13 are given.

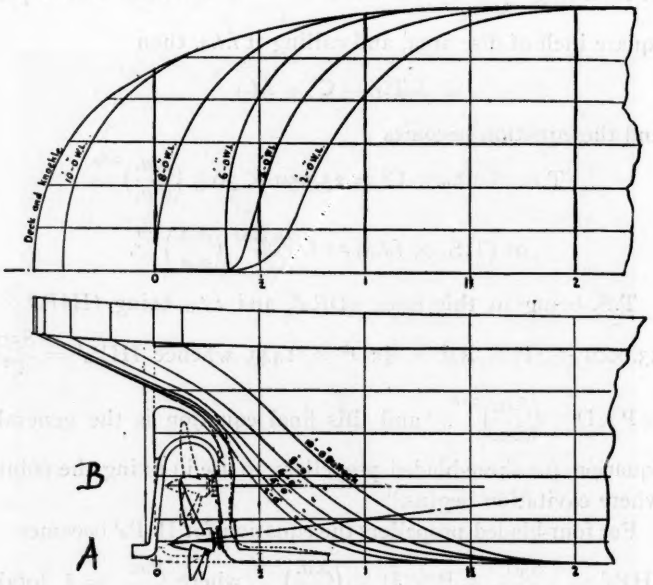


FIG. 12.

Both vessels have a single screw working directly in the wake of the stern post.

The nominal block coefficient of Fig. 12 vessel was approximately .87, and the slip block coefficient corrected for position of propeller is .90. The nominal block coefficient of Fig. 13 vessel was .54, but corrected for fineness of midship section and for position of propeller, it is .915.

The thrust deduction factor for Fig. 13 is found on Line C–2 of Fig. 2, while that for Fig. 12, with the propeller placed in the position marked A, is found on Line C–1. With the propeller placed in the position marked B, the value of the thrust deduction factor is more than doubled over that obtaining in the A position.

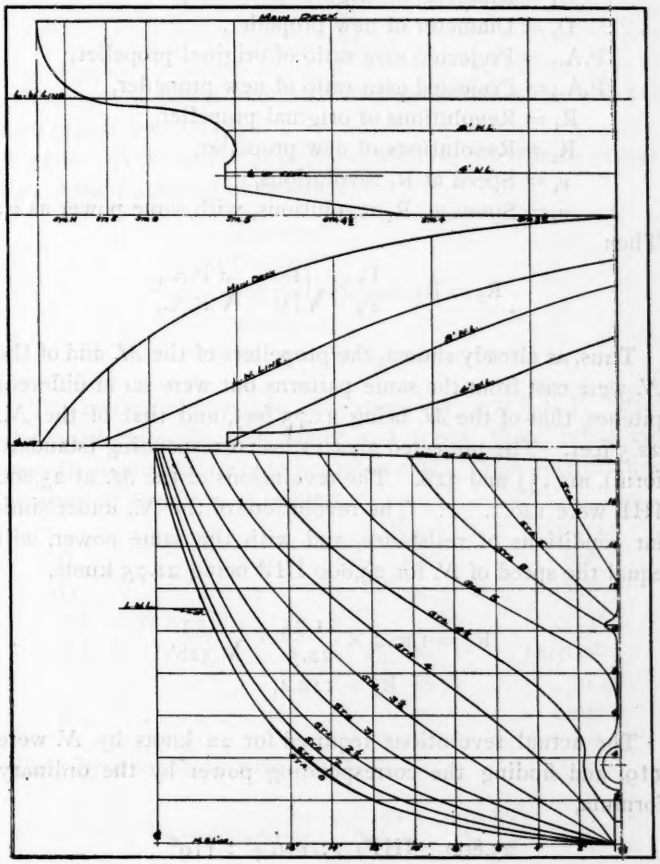


Fig. 13.

HAVING THE PERFORMANCE OF ONE PROPELLER TO ESTIMATE THE REVOLUTIONS OF ANOTHER OF DIFFERENT PITCH, DIAMETER AND PROJECTED AREA, THE IHP OR S.H.P. BEING THE SAME AS WITH THE ORIGINAL.

Let P_1 = Pitch of original propeller,
P_2 = Pitch of new propeller,
D_1 = Diameter of original propeller,
D_2 = Diameter of new propeller,
$P.A._1$ = Projected area ratio of original propeller,
$P.A._2$ = Projected area ratio of new propeller,
R_1 = Revolutions of original propeller,
R_2 = Revolutions of new propeller,
v_1 = Speed at R_1 revolutions,
v_2 = Speed at R_2 revolutions, with same power as v_1.

Then

$$R_2 = R_1 \times \frac{P_1}{P_2} \times \sqrt{\frac{D_1}{D_2}} \times \sqrt[4]{\frac{P.A._1}{P.A._2}}.$$

Thus, as already shown, the propellers of the *M.* and of the *N.* were cast from the same patterns but were set at different pitches, that of the *M.* being 21.75 feet, and that of the *N.*, 22.5 feet. The projected area ratios corresponding (standard form), are .33 and 328. The revolutions of the *M.* at 25,800 IHP were 120.2. ∴ The revolutions of the *N.*, under similar conditions of resistance, and with the same power, will equal the speed of *N.* for 25,800 IHP being 21.75 knots,

$$R_2 = 120.2 \times \frac{21.75}{22.5} \times \sqrt[4]{\frac{.33}{.328}},$$

$$R_2 = 116.4.$$

The actual revolutions required for 22 knots by *N.* were 119, and finding the corresponding power by the ordinary formula,

$$25{,}800 : IHP_d :: \overline{116.4}^3 : \overline{119}^3$$

$$IHP_d = 27{,}570.$$

Should the revolution equation be used to find R_2,

$$R_2 = 116.4 \sqrt[4.35]{\frac{27{,}100}{25{,}800} \times \frac{22}{21.75}},$$

Y being equal to 4.35 for a projected area ratio of 328,

$$R_2 = 116.4 \sqrt[4.35]{\frac{27{,}100}{25{,}800} \times \frac{22}{21.75}},$$

$$R_2 = 118.05.$$

The actual power required on trial for 22 knots and 119 revolutions was 27,100.

Again: A destroyer to make 29 knots is fitted with propellers of the following dimensions:

P = 104″,
D = 92″,
P.A. ÷ D.A. = .55,
Blades = 3,
Form = Standard.

The estimated power for this speed is 15,400 S.H.P. Find the revolutions for this power and speed, there being two vessels of similar form to compare with. The data of these comparing vessels is as follows.

	No. 1.	No. 2.
P	82″	80″
D	92.5″	88″
PA. ÷ D.A.	.60	.60
S.H.P.	15,400	15,400*
v	28.75	30.4*
R	559	608*

Then by comparing with No. 1,

$$R_2 = 559 \times \frac{82}{104} \times \sqrt{\frac{92.5}{92}} \times \sqrt[4]{\frac{.60}{.55}},$$

$$R_2 = 451.7,$$

*Doubtful. Power data for No. 1 more reliable.

and with No. 2,

$$R_2 = 608 \times \frac{80}{104} \times \sqrt{\frac{88}{92}} \times \sqrt[4]{\frac{.60}{.55}},$$

$$R_2 = 467.5,$$

It is further expected that 29 knots may be made with 14,600 S.H.P. and 31.6 knots with 20,000, find the resultant revolutions:

By No. 1,

$$R_d = 451.7 \sqrt[2.85]{\frac{14,600}{15,400}} = 443.3.$$

Y for a projected area ratio of .55 being equal to 2.85.

For 31.6 knots and 20,000 S.H.P.,

$$R_d = 428.16 \sqrt[2.85]{\frac{20,000}{14,600} \times \frac{31.6}{29}} = 510.2.$$

By No. 2,

$$R_d = 443.1 \sqrt[2.85]{\frac{14,600}{15,400}} = 458.8.$$

and for 31.6 knots and 20,000 S.H.P.,

$$R_2 = 434.8 \sqrt{\frac{20,000}{14,600} \times \frac{31.6}{29}} = 528.2.$$

VARIATION OF PROJECTED AREA RATIO FROM THAT OBTAINED FROM CHART—CHECKING OVERLOAD CAPACITY BY MEANS OF CAVITATION EQUATION.

The general equation for cavitation has already been given as

$$*IHP_{Cav.} = \frac{850}{C^2} \times P \times D \times \left(\frac{p.a.}{d.a.}\right)^{2.82} - 3 \text{ bladed},$$

$$IHP_{Cav.} = \frac{850}{.865C^2} \times P \times D \times \left(\frac{3}{4}\frac{p.a.}{d.a.}\right)^{2.82} - 4 \text{ bladed},$$

$$IHP_{Cav.} = \frac{855 \times .75}{C^2} \times P \times D \times \left(\frac{3}{2}\frac{p.a.}{d.a.}\right)^{2.82} - 2 \text{ bladed}.$$

* Where the condition of the propeller is that of reduced diameter the equation becomes

$$IHP_{Cav.} = \frac{850}{C^2} \times P \times D \times A^{2.82} \times \left(\frac{p.a.}{d.a.}\right)^{2.82}$$

in which A is the diameter reduction factor.

These equations are still further modified for propellers of reduced diameter, by the introduction of the factor A^3 in the denominator. Where the reduction of diameter is small, this value of A^3 may safely be omitted as it increases the value of $IHP_{Cav.}$, and its omission slightly lowers the value of $IHP_{Cav.}$, so that if the calculated value of $IHP_{Cav.}$ with A^3 omitted is greater than the maximum IHP of the engine for any projected area ratio, that ratio can be used without danger of cavitation. It may be desirable to state that A is, as throughout this work, the value of the diameter, or better, tip speed reduction factor.

To illustrate by an actual vessel:

E. Hull data.

L.L.W.L. = 380 ft. Nominal B. C. = .629.
B = 47 ft. 8 ins. Slip B. C. (single screw) = .67.
$\frac{B}{L.L.W.L.} = .123.$

Speed 14½ knots — effective horsepower for this speed = 1,960. Maximum IHP of engine = 4,500; maximum diameter of propeller that can be carried = 17 feet. Revolutions for 14½ knots about 82.

Assuming 89 revolutions as those for maximum power, and entering chart 6 with the resultant tip speed, 4,754 feet, and with a constant IHP = 4,500, and solving for reduced diameter, the following propeller results:

P = 20 feet 3 inches.
D = 17 feet.
R = 89.
Four blades.
p.a. ÷ *d.a.* = .413.
IHP = 4,500.
Speed = 15.77.
D.E.H.P. = 2,640.

Entering Chart 6 again, with these values of P, D and R and with several values of *p.a.* ÷ *d.a.* less than $\frac{3}{4} \times .413$, and solving as explained in the analysis of a propeller, values of IHP, D.E.H.P., and v are obtained for these different values of projected area ratio.

These values are then inserted in the power equation and in the revolution equation, which become

$$IHP_d = IHP \times \left(\frac{15.77}{v}\right)^{3(1-X)} \times \left(\frac{2{,}640}{D.E.H.P.}\right)^{X}, \text{ and}$$

$$R_d = 89 \sqrt[Y]{\frac{IHP_d}{IHP}} \times \frac{15.77}{v}, \text{ for } 15.77 \text{ knots, and}$$

$$IHP_d = IHP \times \left(\frac{14.5}{v}\right)^{3(1-X)} \times \left(\frac{1{,}960}{D.E.H.P.}\right)^{X}, \text{ and}$$

$$R_d = 89 \times \sqrt[Y]{\frac{IHP_d}{IHP}} \times \frac{14.5}{v} \text{ for } 14\tfrac{1}{2} \text{ knots.}$$

These results are shown plotted on Fig. 14, and are marked

IHP_d for 15.77 knots,
IHP_d for 14.5 knots,
R_d for 15.77 knots,
R_d for 14.5 knots.

Now, solving the equation for cavitation,

$$IHP_{Cav.} = \frac{850}{1.075^2 \times .865} \times 17 \times 20.25 \times \left(\frac{3}{4}\frac{p.a.}{d.a.}\right)^{2.82}$$

omitting the values of A^3 in the denominator, the values giving the curve on Fig. 14, marked cavitating IHP, are obtained.

By comparing this curve with the ordinate for 4,500 IHP, the maximum power of the engine, it is seen at once that at the full diameter condition of the propeller, that is at a total projected area ratio of .324, the minimum value of cavitating IHP is 5,200, so that the propeller has a leeway of at least 700 IHP before cavitation begins.

In other words, retaining the pitch at 20 feet 3 inches and

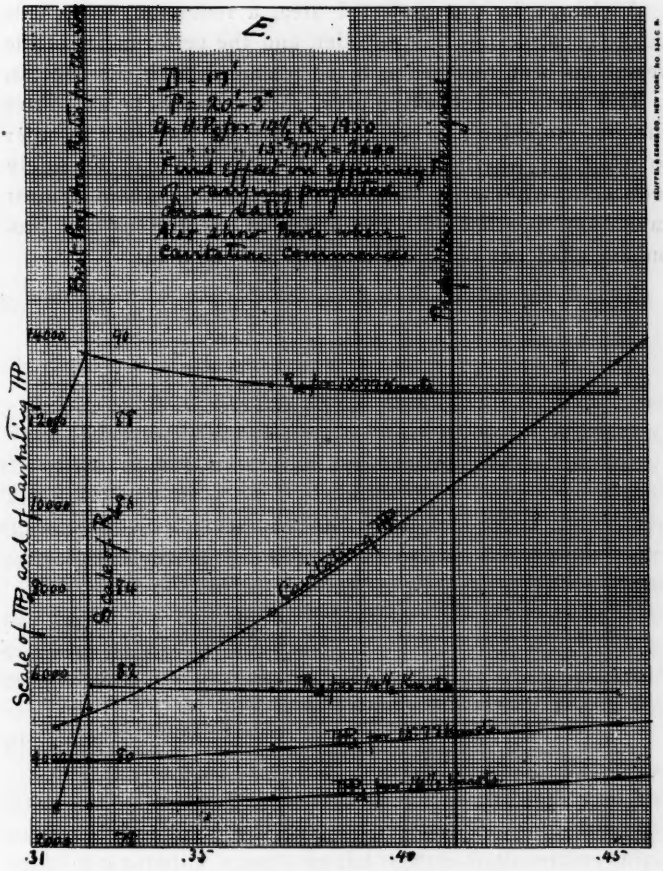


FIG. 14.

the diameter at 17 feet, the projected area can safely be reduced from .413 to .324, the revolutions for $14\frac{1}{2}$ knots increasing from 81.75 to 81.85, while the IHP_d for this speed reduces from 3,470 to 3,000 and the propulsive efficiency increases from $\frac{1,960}{3,470} = 56\frac{1}{2}$ per cent. to $\frac{1,960}{3,000} = 65\frac{1}{3}$ per cent.

A change in the projected area, a reduction, was made before constructing the propeller, and the performance of the vessel has been reported as being phenomenal in its success.

This method of checking areas should always be used after the first propeller has been obtained from the chart in order to ascertain whether the area of projection can be safely reduced or whether it should be increased to guard against cavitation, together with the effect on revolutions and propulsive efficiency of such change as may be made.

PACKING IN THE U. S. NAVY.

A DESCRIPTION OF VARIOUS TYPES USED AND METHODS OF TESTING THEM AT THE ENGINEERING EXPERIMENT STATION.

By Lieut. (J. G.) Alex. M. Charlton, U. S. N., Member.

Before obtaining its supply of packing for each year the Navy Department draws up specifications, which are sent to the various manufacturers and dealers throughout the country. The specifications show the classes of packing desired and the amount of each class required. Bids are opened in the latter part of each year for packing to be used in the ensuing year.

The award of contract is made to the lowest bidder whose packings have been found satisfactory for the requirements of the naval service, and the right is reserved to reject the bid of any firm, irrespective of prices quoted, whose packings are not considered satisfactory to the Bureau of Steam Engineering.

Until the establishment of the Experiment Station at Annapolis the Department was rather at the mercy of the contractors, as there was no good method of establishing the value of a packing except by the reports from various ships, which were often conflicting. Now, however, to have a bid considered, the manufacturer must have had his packings tested at the Experiment Station, and as the various brands are tested under identical conditions, the real comparative worth of a packing is established.

The packings called for under the specifications of 1913 and 1914 are as follows:

1. Spiral gland packing, in sizes three-eighths to one and

one-quarter inches; to be of the highest grade, square or rectangular in section, suitable for use under all steam pressures up to 300 pounds per square inch; to be made from the best quality of long-fiber asbestos cloth, with tubing block, thoroughly treated and saturated with a mineral lubricant which shall remain solid at 110 degrees F. The packing will contain a rubber-spring backing, or have equivalent means of cushioning, and will be sufficiently pliable to flow or move toward the rod as the wear takes place, and will exert a lateral pressure when the glands are tightened.

2. Spiral gland packing for valve stems; in sizes from one-eighth to one inch, as required; to be of the highest grade packing, suitable for use under all steam pressures up to 300 pounds per square inch; to be pure, long-fiber asbestos rope, thoroughly graphited and lubricated with vulcanizable gums.

3. Spiral gland packing for use in dense-air ice-machine stuffing boxes, in conjunction with metallic packing, with pressures of 250 and 75 pounds per square inch; in sizes from one-quarter to three-quarters inch, square or rectangular in section.

4. Sheet packing; rubber with cloth insertion; for cold-water use and electrical apparatus. The rubber must contain at least 35 per cent. of pure Para rubber.

5. Sheet packing; rubber with brass-wire insertion; suitable for use with hot and cold water, and for all steam pressures up to 160 pounds per square inch. The coatings of rubber will be of the same thickness on both sides of the wire insertion; the composition of the rubber will be such that it will not become softened by the action of the steam, and will not be cut through by the wire insertion under the pressure exerted by the flanges when the bolts are tightened up. The wire insertion will be woven from brass wire about 0.012641 inch thick and about twenty-four meshes to the inch.

6. Compressed fiber sheet packing, asbestos; suitable for use with superheated steam at 300 pounds pressure and 625 degrees F. temperature; in commercial widths and thicknesses from one-thirty-second inch up. The material for

thicknesses up to one-sixteenth inch must be homogeneous in texture, and not made up of layers cemented together. The substance used as a binder must be such that it will not disintegrate at the high temperatures to which it is liable to be subjected, and will at all times prevent the asbestos fibers from absorbing moisture.

7. Flax packing; in sizes as required; to be made of best selected long-line Russian flax, well and evenly impregnated with pure tallow; to be free from warp or core, from flax tow, jute or other foreign fibers or substances, and from oils or greases other than pure tallow, which latter must not be in excess of 50 per cent. by weight of finished packing. The length of staple must be such that when a section of packing 20 inches in length is carefully unraveled and combed out with a coarse comb, it will give a brush of at least 12 inches.

8. Tuck's packing; round and square, in sizes as required, according to specification 33P7a. The specifications for this packing are quite elaborate and will not be included here. They have to do with rubber content, friction, tensile strength, heat tests, etc.

Separate specifications are issued for boiler manhole and handhole gaskets, both for the standard sizes and for odd sizes, to be made from templates sent to the contractors from time to time. All these gaskets are required to be of the standard folded (seamless or jointed) asbestos-metallic type, or of the compressed asbestos-fiber type.

No specifications are issued for metallic-ring packing to be purchased in quantities, the specifications being drawn up for lots as required.

Besides the types of gaskets and packing mentioned by the specifications, the following may be used: corrugated copper (flat) gaskets, made with a copper jacket, bent into a flat C-form, and filled with asbestos for cushioning, shown in Figs. 1, 2 and 3; gaskets made from V- or C-shaped sections of coppered steel, built up with asbestos between each two sections, shown in Figs. 4 and 5. This latter type is now

being made from Monel metal, in an effort to prevent corrosion.

These two latter types of metal and asbestos gaskets are used both for pipe joints and for manhole and handhole gaskets on boilers.

Another type of gasket, so far developed only for boiler handholes, consists of an S-shaped piece of non-corrosive sheet metal, with asbestos in each loop of the S, as shown in Fig. 6.

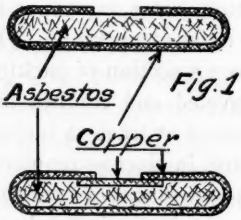


Fig. 1

Fig. 2

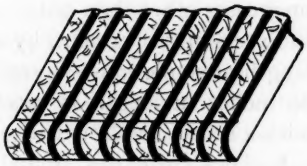


Fig. 4

Alternate layers of metal and asbestos.

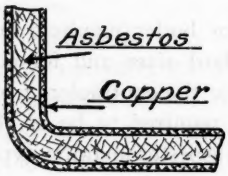


Fig. 3

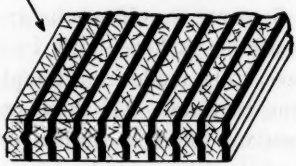


Fig. 5

Fig. 6

Mention may be made here of various other materials used in making high-pressure steam joints. These are: red lead, putty and wire gauze; manganesite, smooth-on; ferro compound, etc. Joints with ferro compound are made either by working the compound into putty-like shape and applying it to the flanges so that it will spread out evenly between the

surfaces of the joint when the bolts are tightened or when the flanges are well lined up and very smooth, by painting the face of each flange with a wash of the compound. Manganesite is generally used for joints on turbines.

METHODS OF TESTING PACKING.

The apparatus for testing *Spiral Gland Packing* consists of a series of stuffing boxes, supported on framework, secured to the tops of two pumps. Working in these stuffing boxes are hollow piston rods, receiving their motion from the steam pistons of the pumps, and so arranged that the rods will be kept heated by the steam admitted to the interior from the steam cylinders. Connections are made by piping between the cylinders and the interior of each of the stuffing boxes, so that packing which may be fitted in these boxes will be subjected to practically the same conditions as when in service.

The glands are packed with the various brands of packing, and tests are run until the packing fails. The two pumps are arranged to run at the same number of strokes per minute, so that each type of packing will be subjected to the same number of reversals. Records are kept of the time the gland is tight without attention, how often the nuts have to be taken up, when extra turns of packing are inserted, and when it is necessary to renew the packing entirely. The condition of the packing when taken out is observed carefully, as this usually gives an idea of the cause of failure.

No special apparatus is rigged for tested *Valve-Stem Packing*, but the packing is inserted in the glands of valve stems about the station, and thus subjected to working conditions under steam pressure up to 300 pounds.

The method of testing *Ice-Machine Packings* consists of filling the stuffing boxes of the piston rods and valve stems of both the compressor and expander cylinders of the ½-ton Allen dense-air machine in use at the station, with different brands of packing, and noting their behavior under working conditions. In the tests run a different brand of packing was

fitted in each stuffing box, so that six brands were under test at one time. As in the other tests, the time of service, condition on removal, etc., were carefully observed.

Sheet Packing; Rubber with Cloth Insertion, for Cold-Water Use.—Twelve plain flanges of a six-inch pipe line, carrying two hundred pounds pressure of cold salt water, were made up with the packings submitted, the different brands being used in regular sequence. The joints were about two and a-half feet apart, in a straight run of pipe, connected at one end to a simplex direct-acting pump, and having at the other end a relief valve set to open at about 210 pounds. This relief valve dripped slightly at each stroke of the pump throughout the test, giving a ready means of checking the maintenance of the pressure. After being under pressure for thirty-five days without indication of failure of any of the joints, the blank flange at the relief-valve end of the line was removed, the pipe was allowed to drain and to dry out, to simulate the conditions of repairs in the system. This was done at intervals of a week thereafter, in all seven times, but no change in the condition of the packings resulted. After seventy-two days of test the joints were broken, and the gaskets were in as good condition, apparently, as when they were put in. The joints were left open for six days, exposed to sun and air, and were then made up again, a thin coat of oil and graphite being applied to the free side of each gasket (the old one) to facilitate its removal again without injury to the gasket. When pressure was again put on the line not a joint leaked.

Sheet Packing; Rubber with Wire Insertion, Suitable for Use with Cold and Hot Water and Steam Pressure up to 160 Pounds.—The apparatus for testing sheet packing under steam pressure consists of four lines of six-inch pipe, each having seven joints, so that twenty-eight gaskets may be tested at the same time. These pipes are placed side by side, and are in communication with each other at one end through heavy tee castings, but each pipe is closed at the other end by a blank flange. Steam at 180 pounds pressure

enters at the tee end, and the water of condensation is trapped off. The steam test at 180 pounds is considered sufficient for packing under this item, for there is enough water of condensation to simulate the hot-water condition, and if packing will stand up under hot water it will stand up under cold water at the same pressure.

Compressed Fiber Sheet Packing, Asbestos.—In testing this packing, an apparatus similar to that used in testing the rubber sheet packing is used, except that the blank flanges at the ends of the pipes are tapped for ½-inch circulating pipes. Connections are made with the apparatus so that steam at boiler pressure, which has previously passed through a superheater, is admitted at the end where the six-inch pipes are joined together by the tee castings, through a one-inch pipe extending internally, and fitted with branches which serve to distribute the steam and direct an equal quantity into each of the six-inch pipes. The ½-inch circulating pipes at the opposite or outlet ends of the apparatus unite into one pipe leading to the auxiliary steam line, which carries a uniform pressure of 150 pounds. By means of a valve in the one-inch pipe the quantity of steam passing through the apparatus is regulated. The whole apparatus is thickly clothed with a magnesia pipe covering to reduce the loss of heat by radiation. A recording pressure gage attached to the piping gives a daily record of the steam pressure, and thermometer cups at the inlet and outlet ends of each six-inch pipe afford means of ascertaining the temperatures within the apparatus. Four gaskets of each brand of packing are put in, one in each of the four pipes, at different positions along their lengths. This arrangement allows seven brands to be tested simultaneously. The pressure varies from 260 to 310 pounds, depending on the boiler in use, and the temperature varies between 525 degrees and 600 degrees F.

The gaskets are under pressure for eight hours daily during the tests, a cooling period of sixteen hours a day being allowed to note its effect on the joints. The relative value of the packings is determined by the length of time they stand up

before leakage occurs, the time elapsing before renewal is necessary being neglected for the purposes of this test.

Boiler Gaskets are tested by putting them into the B. & W. and Niclausse boilers in use at the station, and carefully noting their behavior.

The special types of gaskets mentioned have been placed in various joints about the station where they are subjected to working conditions, no special apparatus being employed for their test.

Metallic Ring Packing is tested in the apparatus used for testing spiral gland packing. As yet few brands of this type of packing have been tested.

CONCLUSIONS.

The following conclusions may be drawn from the results of tests on a great variety of packing extending over a period of five years.

No high-pressure spiral gland packing has yet been developed that will satisfactorily stand 300 pounds pressure for a reasonable length of time. So, in recommending a packing for use, it is done because it is the cheapest of several that gave about the same length of service, and not necessarily because it is entirely satisfactory.

The valve-stem packing recommended for use has proved satisfactory.

The special ice-machine packings have not proved satisfactory. High-pressure spiral packing is just as satisfactory as the special types, and as good, if not better, results are attained by using soft packing in combination with metallic packing.

Many brands of *rubber sheet packing* for cold-water use have been tested, and all seemed able to last indefinitely. In fact, almost any kind of packing will stand up under cold-water pressures up to 300 pounds.

Rubber sheet packings with cloth, wire, or pure rubber insertion are not suitable for use with steam pressures of 300 pounds or even 250 pounds. The rubber becomes soft, and is apt to blow out, leaving channels for the steam to leak

through. Also, the rubber squeezes into the pipe, cutting down the steam area, and allowing detached pieces to be blown through the steam lines.

Woven asbestos packings are unsuitable for use with steam pressures up to 300 pounds. The rubber compound forming the coating which is intended to protect the asbestos from the action of the steam and water of condensation wears away in spots, leaving the asbestos exposed to the action of steam and water, and at the same time permitting minute channels to form, through which steam and water can escape.

"*Rolled*" *asbestos packing* (compressed fiber) is the most satisfactory for high-pressure superheated-steam joints, and, with the present low price of good quality packing of this type, it is believed that it would be economical to use this style of packing for all joints, either water or steam.

Tests on *slip-joint packing* have proved that high-grade spiral woven-asbestos gland packing is better for slip joints than the flexible matallic packings offered, and the special specification for slip-joint packing is now omitted.

Boiler gaskets.—None of the types tested give satisfactory life. As long as the manhole or handhole plates are undisturbed the joints remain tight, but unless the surfaces are very smooth the same gasket cannot be used when the joint is again made up. The gasket is baked hard by the action of the steam, and loses its elasticity, and if the plate is put back a fraction of an inch removed from its former position, the joint will leak. In connection with getting the surfaces clean before making the handhole joints on a B. & W. boiler, the use of a mirror arranged like a dentist's mirror, is suggested. This would enable the inner surfaces to be seen, and would facilitate the removal of scale and old gasket material, which make for leaky joints.

None of the gaskets of the "metal and asbestos combined" type have proven satisfactory with high steam pressures. Small irregularities appear on the metal surfaces when the joint is first made up. These remain in spite of the annealing

process and offer channels for steam leakage while the joint is in service.

Joints made up with metallic compounds are satisfactory when the flange faces are well lined up and very smooth, but in some cases the joints are hard to break, the two faces being joined so tightly together that the flanges themselves are sometimes broken in trying to break the joints.

The following table gives the uses to which different packings supplied are applicable.

Type of packing.	*Name of representative packing.	Use.
Spiral-gland packing, sizes $\frac{5}{8}$-inch to $1\frac{1}{4}$ inches.	Anchor high pressure, T stock.	Piston rods and valve stems up to 300 pounds pressure.
Spiral-gland packing, sizes $\frac{1}{8}$-inch to 1 inch.	Heliobestos Mogul	Valve stems up to 300 pounds pressure.
Spiral-gland packing, sizes $\frac{1}{4}$ to $\frac{3}{4}$-inch.	Belmont, style 102.....	Ice-machine stuffing boxes for pressures of 250 pounds and 75 lbs.
Rubber-sheet packing with cloth insertion.	.....	Gaskets for cold water and electrical use.
Rubber-sheet packing with brass-wire insertion. Hot and cold water and steam up to 160 pounds.	Akron red sheet packing.	Gaskets for hot and cold water and steam up to 160 pounds.
Compressed fiber-sheet packing, asbestos.	Consolco H.P. No. 500..	†Gasket material for high pressure and superheated steam.
Flax packing.....	.....	Rod packing for water end of pumps and hydraulic machinery. Use alternate layers of flax and Tucks.
Tuck's packing.....	.....	
Boiler gaskets.....	Durable, McKim standard asbestos.	Boiler hand-hole and man-hole gaskets.

* These may be varied from year to year as contracts are let.
† This material is suitable for all gasket joints except those subject to the action of oil.

Best results in making joints are obtained by making the outside circumference of the gasket tangent to the bolt holes and by using as thin a gasket as possible. These allow a

tighter joint and require less packing. If greater care were exercised by the pipe fitters when a ship is built, in getting the flange faces exactly lined up and close together, there would be less gasket trouble.

Tests of the effect of size and spacing of flange bolts on the life of a gasket will probably be carried out in the future.

While the tests at the Experiment Station do not exactly simulate service conditions they do give a comparison of the various types of packing. An endeavor is made to select the most economical packing for use in the service. Often a high-priced packing will last so much longer than a cheaper one that the cost per hours of service for the high-priced packing is much below that of the so-called cheaper one.

ORGANIZATION OF THE ENGINEER DIVISION ON BOARD A MAN O'WAR.

By Lieut. Commander A. W. Johnson, U. S. N., Member.

The above is the title of an article that appeared in the Journal in November, 1901, written by Lieutenant, now Captain, C. W. Dyson, U. S. Navy. I will quote the opening paragraph because it is as pertinent today as when Captain Dyson wrote it:

"One of the most important problems an officer finds staring him in the face is that of forming the force detailed to the Engineer Division into such an organization as will produce that smooth and clock-work action which is required in a military body. Everyone must have a place in all work and drill of the division, and everyone must know his place. To make each man's station bill as simple as possible, so that he may be able to commit to memory, without any great effort, his duties in all drills and in the work of the department it should be so laid out as to confine him to one particular position of the department."

The writer then proceeds to describe the organization and the watch, quarter and station bill for a ship of the *San Francisco* class. In those days the Regulations did not permit the engineer's force to stand watch in four. It was customary to divide the engineer's division into three sections, and to split the second relief section into two parts when the division stood watch and watch for full power.

Other articles that have appeared in the Journal bearing on the subject are: "Notes for general and routine work of the Engineer's Division, U. S. Naval vessel," by Lieut. H. C. Dinger, 1904; and "A plea for a standard organization * * *

and method of management of the Engineer Department," by Lieutenant Commander W. B. Tardy, U. S. N., in 1911.

Since Captain Dyson's article was written ships have increased greatly in size and power, and the engineer complements have grown from the 120 men of the *Indiana* class to something like 280 in the *Delaware*. The regulations now permit steaming with watch in four in cruising, and much has been done in modifying and extending the organization of the engineer departments to meet present needs. Much, too, has been written about the organization of the engineer dement on board ship. But the same lack of uniformity exists today as when Captain Dyson wrote, "It is hoped that the publication of the views and ideas contained in this article may bring out the views on the same points, and on any others relating to the subject, of other officers of the service, that the organizations of the engineer division of our ships may be made more uniform."

Many vessels now have practically identical organizations; others differ radically. Some have excellent ones; while others are not so good. While the engineer officer should have a free hand in organizing his division, it would be of great value to him when commissioning a new ship to have as a standard on which to base his own organization a description of an organization which has proved satisfactory and stood the test of time; something by which he may profit from the experiences of others, that will relieve him of the necessity of devoting his time experimenting with many details that have been tested out in other ships. With a good standard organization completely worked out and published in pamphlet form, the engineer officer, after making such alterations as necessary, could distribute the pamphlets to his officers and petty officers, saving for himself an immense amount of labor.

Another advantage in standardizing the organization would at once be apparent to officers and men when transferred from one ship to another, their familiarity with it enabling them quickly to fall into their new duties. I believe the advan-

tages so far outweigh the disadvantages that officers should put aside their hobbies and adopt some uniform system in future. The same argument applies to the incessant changes and alterations going on everywhere. Not that I am opposed to progress, but rather, that we should endeavor to attain perfection in the use of the appliances at hand, and not waste too much time in experimenting.

In all our battleships the several deck divisions are divided into four sections, and, until recently, all the engineer divisions were divided into four sections. In some of the engineer departments the organization of the four sections was defective, and to correct it the five-section arrangement was suggested, and was adopted in a number of vessels. Now we hear of a six-section organization for the engineer division. The four-section arrangement is absolutely correct, if properly made and, as it fits in with the regular organization of the ship, I fail to see why it should ever have been abandoned.

Another suggestion that recently has been made is that of dividing the engineer department on board ship into three divisions of four sections each, the senior engineer officer being the head of the department, with three divisional officers under him. This seems reasonable. The logical arrangement then would be, one division to consist of the fireroom stations, one of engine-room stations, and another for all other stations, each division being divided into four sections for watch standing. This arrangement is applicable to the organization here shown with very few modifications.

The following rules drawn up by Lieutenant Commander Jessop on the *Arkansas* are quoted because they should be observed for all organizations aboard ship.

Rule 1.—An organization to be efficient must be automatic. This means that all daily routine duties must be carried on by the organization without specific orders. That all emergencies must be cared for by the organization without special preparation. That liberty shall not break up the organization so that routine work suffers. That messes shall remain intact under all conditions of watch standing.

Rule 2.—Authority engenders responsibility, and, conversely, responsibility presupposes authority.

This rule is made effective by the following order: Orders shall be issued only through the officers and petty officers concerned, and never direct to the individual doing the work unless in case of emergency, in which case the fact that an order has been issued shall be communicated to the officer or petty officer concerned immediately.

Rule 3.—Simplicity of organization, with completeness of detail is essential to efficiency.

This is based upon a very decided idea that if the average man is given a thorough knowledge of all his duties and knows that he will not have any other duties while he holds his number, he will be contented, and will in nearly all cases do his work, where, if he is never quite sure what his duties next minute may be, he will not be contented and his work will be poor.

To carry out the above rule it is essential that each section of the steaming sections be distributed for cleaning and repair and for emergencies, so that each station will have at least one man from each section.

The organization is so arranged that whether the force is standing a watch in four, three or two, the messes remain intact, which saves an immeasurable amount of office work, keeps the men together, and answers Rule No. 1 as to the organization being automatic."

In the watch, quarter and station bill shown the engineer force is divided into four equal sections for watches and liberty, and into stations for cleaning and repair work. The names are arranged by sections in vertical columns, and by stations in horizontal rows. This arrangement provides a combined muster list for sections and stations.

The advantage claimed of the five-section arrangement is that all men not assigned to the engine and firerooms are placed in the fifth section, by which the officers do not have to account for men who might be absent on special details.

In the arrangement herewith submitted the combined sec-

tion and station list provides for a simple and accurate muster, and the fifth section is purposely omitted because it does not fit in with the four-section arrangement of organization established in all other departments of the ship.

Each man is assigned to a definite section and station, but his particular duties are not specified in the bill. The squad system is applied, and the petty officers or squad leaders are responsible to their officers for making the necessary details of the men to properly carry on the work, and for giving them the necessary instructions to meet the requirements of the various drills and emergencies arising. In doing this the petty officers must be guided by the special orders they may have received, by the general instructions laid down on each individual vessel, and by their own experience.

Each man is assigned a number which indicates his division and section, as customary in all ships; and by using numbers of four figures each, his station and rate can be indicated as well. The third figure corresponds to the number of his station, and the fourth number indicates his rank on the station. To illustrate: No. 9331 would indicate the first man (W. T.) of 3d station (No. 3 F. R.) of 3d section of 9th division.

In many vessels provisions are not made for manning all stations at all times and under all conditions. This is very important. It will be noticed in the station bill shown that each station has an equal number of men assigned to it from each section; so, no matter which sections are on watch or on liberty, there are still men available from the other sections to properly man all stations.

In some ships nowadays it is not possible to stand watch in four because of vacancies in complement or because the cruising speeds are too high. This is particularly noticeable in the older vessels of the Navy when steaming in company with the later ships. Some engineer officers are not satisfied, therefore, with the four-section arrangement. In such cases it is necessary to put the men in watch in three for cruising,

or even in watch and watch, in which case one of the sections would have to be split up.

The watch, quarter and station bill is written on a single sheet and posted on a special board. Opposite each man's name is a small hole into which may be inserted a brass nail. Nails of various colors are provided to indicate the special duty a man is performing, whether excused, absent, etc. When a detail is made the yeoman puts in the proper colored nail opposite the man's name, so that at all times the board will show how to account for each man of the engineer's force. When a watch list is made up, as each man's name is written down, a brass nail is plugged in opposite his name on the board; when the sick report is brought in every morning, the names indicated on the list are indicated by plugging in with yellow nails; men on special temporary details are indicated by red nails; on furlough, by white nails; and in confinement, by black nails. All men who have no nails opposite their names are available for work on their stations. A neat way to color the nails is to drop a bit of sealing wax of the proper color on the head of the nail. Paint soon wears off. This method of accounting for men is very simple. In some ships the same method is applied, but instead of using colored nails several holes are placed opposite each name to indicate the different assignments. This requires too large a board. It is desirable to keep a list of the men's names alphabetically arranged with watch numbers opposite to quickly locate the names on the station board. Columns may be added to the station bill showing men's sleeping compartment, pay number, etc.

The duties of each station for fire, collision and other drills, may be shown in the columns opposite each station, or may be separately shown under appropriate headings as is done below.

Great care should be taken in arranging the men into messes to secure the best results. Men who stand watch together should be in the same mess, and there should be one or more petty officers in each mess, the senior of whom is re-

sponsible for its discipline. The idea is to avoid as many "late messes" as possible, so that mess tables and compartments may be cleaned up promptly after meal hours. For every twenty men there is one mess cook allowed. The engineer force is usually required to detail a man for the scullery and another for the C. P. O. mess, so that it may be advisable to put more than twenty men in each mess. In the bill shown there are 240 men, which allows 12 messes, or three messes to each section. If an uneven number of messes were allowed the distribution would not be so easy. An odd mess might be provided for all steamer crews, evaporator and ice-machine men, and others who are usually late for mess. It will be noticed in the above bill that in each section these men are detailed to the same mess. In making out watch lists for auxiliary watches, men belonging to the same mess should be in the same watch. Unless care is taken in arranging messes there will be many "late messes" throughout the ship.

When a ship is first commissioned, and before she has thoroughly shaken down, there is likely to be some confusion, by reason of the men not all being individually suited to their new stations. For this reason it is not advisable to continually shift the men's numbers as they are changed to the various stations; but when once shaken down, it is well to make no further changes except at the end of each quarter, and to change the numbers at that time. This especially applies to the messmen. Some officers prefer not having special numbers for the messmen, but to detail them from any station and to indicate them by a special plug.

This four-section arrangement is very well suited for battle and general drills; it also fits in well with the ship's organization for liberty, and it is much more flexible and automatic than the five-section arrangement. Two out of the three senior engineers of the *Utah* have spoken adversely of the five-section arrangement there used.

In making out the steaming watch the following is the procedure in the office. First find out which boilers are to be

used, then take the station board and put the men on watch on the boilers of their regular station, plugging in their names with the brass nail as they are put on the watch list; after all names of the steaming firerooms have been put down, complete the watch list by taking men from other stations, leaving off watch as many men of the cold fireroom stations as possible. In case of any general drill there is no confusion, because everybody on watch stays on watch, while the remainder of the men proceed to their regular stations. Thus every station is properly manned. In case of going into watch and watch, men on watch remain on watch and are reinforced by the first relief or section due next to go on watch. In many ships the organization calls for the second relief to go on watch so as to have the first and third sections and second and fourth sections on watch alternately. The latter arrangement is defective because it does not require the men who have been off watch longest to go on as first relief.

The first relief goes below and relieves all men of the watch who do not regularly belong to the station. The latter go to their regular stations and report to their leading petty officers and perform such duties as directed. This is explained in greater detail further on.

Station.	First section.			Second section.			Third section.			Fourth section.		
	No.	Rate.	Mess.	No.	Rate.	Mess.	No.	Rate.	Mess.	No.	Rate.	Mess.
1 No. 1 fireroom.....	W1	CWT										
	9111	WT	11	9211	WT	14	9311	WT	17	9411	WT	20
	9112	F1c	11	9212	F1c	14	9312	F1c	17	9412	F1c	20
	9113	F1c	11	9213	F1c	14	9313	F1c	17	9413	F1c	20
	9114	F2c	11	9214	F2c	14	9314	F2c	17	9414	F2c	20
	9115	F2c	11	9215	F2c	14	9315	F2c	17	9415	F2c	20
	9116	CP	11	9216	CP	14	9316	CP	17	9416	CP	20
	9117	CP	11	9217	CP	14	9317	CP	17	9417	CP	20
	9118	CP	11	9218	CP	14	9318	CP	17	9418	CP	20
	9119	CP	11	9219	CP	14	9319	CP	17	9419	CP	20
2 No. 2 fireroom.....				W2	CWT							
	9121	WT	12	9221	WT	15	9321	WT	18	9421	WT	21
	9122	F1c	12	9222	F1c	15	9322	F1c	18	9422	F1c	21
	9123	F1c	12	9223	F1c	15	9323	F1c	18	9423	F1c	21
	9124	F2c	12	9224	F2c	15	9324	F2c	18	9424	F2c	21
	9125	F2c	12	9225	F2c	15	9325	F2c	18	9425	F2c	21
	9126	CP	12	9226	CP	15	9326	CP	18	9426	CP	21
	9127	CP	12	9227	CP	15	9327	CP	18	9427	CP	21
	9128	CP	12	9228	CP	15	9328	CP	18	9428	CP	21
	9129	CP	12	9229	CP	15	9329	CP	18	9429	CP	21

Station.	First section.			Second section.			Third section.			Fourth section.		
	No.	Rate.	Mess.	No.	Rate	Mess.	No.	Rate.	Mess.	No.	Rate.	Mess.
							W_3	CWT				
	9131	WT	13	9231	WT	16	9331	WT	19	9431	WT	22
3	9132	Fic	13	9232	Fic	16	9332	Fic	19	9432	Fic	22
	9133	Fic	13	9233	Fic	16	9333	Fic	19	9433	Fic	22
No. 3 fireroom.....	9134	Fac	13	9234	Fac	16	9334	Fac	19	9434	Fac	22
	9135	Fac	13	9235	Fac	16	9335	Fac	19	9435	Fac	22
	9136	CP	13	9236	CP	16	9336	CP	19	9436	CP	22
	9137	CP	13	9537	CP	16	9337	CP	19	9437	CP	22
	9138	CP	13	9238	CP	16	9338	CP	19	9438	CP	22
	9139	CP	13	9239	CP	16	9339	CP	19	9439	CP	22
4				M_2	CMM					M_4	CMM	
Fireroom mechanics	9141	MM1	11	...	...	...	9341	MM1	19	9441	MM1	20
	9142	BMk	13	9242	BMk	16	9342	...	...	9442	...	...
5	M_1	CMM										
	9151	MM2	11	9251	MM1	14	9351	MM1	17	9451	MM2	20
Starboard engine-room.....	9152	Oil.	12	9252	MM2	14	9352	MM2	18	9452	Oil.	21
	9153	Oil.	13	9253	MM2	16	9353	Oil.	19	9453	Oil.	22
	9154	Fic	11	9254	Fic	14	9354	Fic	17	9454	Fic	20
	9155	Fac	12	9255	Fac	15	9355	Fac	19	9455	Fac	21
	...	...	...	9256	CP	16	9356	CP	18	...	...	...
							M_3	CMM				
6	9161	MM1	12	9261	MM2	16	9371	MM2	19	9461	MM1	21
	9162	MM2	13	9262	Oil.	14	9362	Oil.	17	9462	MM2	22
Port engine-room..	9163	Oil.	11	9263	Oil.	15	9363	Oil.	18	9463	Oil.	20
	9164	Fic	12	9264	Fic	16	9364	Fic	17	9464	Fic	22
	9165	Fac	13	9265	...	...	9365	...	...	9465	...	...
	9166	CP	11	...	...	...	...	...	...	9466	CP	20
7	X_1	CMM										
Shops.....	9171	...	11	9271	MM1	14	9371	MM2	19	9471	MM2	21
	9172	BSmt	12	9272	BSmt	16	9372	CSmt	18	9472	CSM1	22
8	9173	Moul	13	9273	Fac	14	9873	...	...	9474	...	...
Dynamos, steering and anchor engines, heaters....	...	...	...	X_2	...	...	X_3	...	...	X_4	...	...
	9181	MM2	11	9281	MM2	15	9381	MM1	17	9481	...	...
Evaporators	9182	Oil.	12	9282	Fic	15	9382	Frc	18	9482	Oil.	21
Refrigerator Plant	9183	Fic	12	9283	Oil.	15	9383	Oil.	18	9483	Fic	21
	9184	Frc	12	9284	Fic	15	9384	Fic	18	9484	Fic	21
Boats	9185	Fic	12	9285	Fic	15	9385	Fic	18	9485	Fic	21
	9186	Fac	12	9286	Fac	15	9386	CP	18	9486	CP	21
	9187	CP	12	9287	CP	15	9387	CP	18	9487	CP	21
	...	...	...	...	...	...	...	...	...	W_4	CWT	...
9	9191	WT	11	...	...	...	...	...	...	...	...	...
	9192	Fic	11	9291	...	...	9391	...	...	9491	...	...
Messmen washroom and compartment cleaners.	9193	Fac	13	9292	Fac	14	9392	Frc	17	9492	Fic	20
	9194	CP	13	9293	CP	16	9393	Fac	19	9493	CP	22
	9195	CP	11	9294	CP	16	9394	CP	18	9494	CP	21
	9196	CP	12	9295	CP	14	9375	CP	17	9495	CP	20
	9197	CP	13	9296	CP	16	9396	CP	19	9496	CP	21
	9198	CP	12	9297	CP	16	9397	CP	19	9497	CP	22
10												
Office and store rooms and supernumeraries.	Y_5	...	...	...	...	...	...	...	...	...	...	...
	9101	...	13	9201	...	...	9301	...	...	9401	...	...

NOTE.—The above station bill gives a working bill for actual use in stationing men, making details, etc. This, with a proper station billet, to be handed to each man, with a duplicate kept in engineer's office, and with detailed instruc-

tion as to the duties of each squad, group or station, is all that is essentially necessary for the organization. It may, however, be desirable to have a general station bill for each section posted, wherein, abreast each number and name, are assigned the station or duty; also, if considered necessary, the pay number, locker numbers, boat, station in ammunition party, etc.

CLEAR SHIP FOR ACTION.

The senior engineer officer will direct the officers in charge of stations what special duties they will perform in making the engineer department ready, and they will supervise the work on their stations accordingly. All men of the engineer department will repair to their stations to carry on the work, except those on watch, who will continue with the watch. After inquiring of the commanding officer his desires in regard to the disposition of the engines and fires, as to whether or not the steam will be shut off the whistle, siren and auxiliary machinery, he will give the necessary instructions. The following will also be carried out:

Ship grating bars on protective deck;

Distribute, trim and fill the oil lamps throughout the department;

Ship wrenches and other safety gear on berth deck for operating steam stops, drains, doors and hatches, fuel-oil cut-outs, flood cocks and other safety devices, but do not operate them.

All preparations should be made at this time that will lessen and expedite the work to be done at general quarters. The time element in "Clear Ship for Action" is of secondary importance, the main consideration being thoroughness.

Heavy articles, such as tools and spare parts, should be well secured in place or removed to places where they are least liable to break loose and injure the machinery or personnel.

It is desirable to distribute the fuel oil and reserve feed water in the various double bottoms, so that each will have the same proportion of vacant space for cushioning and lessening the damage from mine explosions.

All watertight doors and hatches should be examined to insure that the gaskets and dogs are in good condition; and all strainers of suctions should be examined and valves worked to see that they are in good order.

GENERAL QUARTERS.

The engineer officer will take charge in the engine room, and will give directions regarding turning off steam on lines above protective deck, shutting down auxiliary machinery, and what disposition is to be made of boilers and main engines, after having ascertained commanding officer's wishes on the subject. He shall have all preparations required from his division in "Clear Ship for Action" performed.

The officer on duty will remain at his post and carry out instructions of the officer of the deck or engineer officer until relieved.

Other officers will go to their stations in accordance with the ship's organization for battle.

The duties to be carried out on the various stations are given below:

Steaming at full speed must be provided for before, during and after action. This may extend over many hours; and while the guns' crews could remain continuously at or near their quarters for a long period of time, it would be necessary to relieve the engineer's force on watch below at fairly regular intervals. This may be effected as follows:

Men who are on watch at the time it becomes necessary for full-power steaming before an engagement, continue on watch until relieved. Men of the first relief section (next due to come on watch) go to their stations and reinforce the men already on watch there, and relieve any men standing watch there who belong to any other fireroom station. These, as soon as relieved, go to their regular firerooms and assist in the work there under their regular petty officers.

The special duties of each individual are not provided for in this watch, quarter and station bill, the squad system being

used instead. Unforeseen casualties, absentees, etc., sure to occur, also make it impracticable to here make the special details. The officers and petty officers in charge of stations and substations will distribute their men so as to obtain the best results with the personnel available.

At the regular hours for relieving the watch, the second and third relief, the two sections off watch relieve those on watch on their regular stations unless specially detailed elsewhere. This routine is continued until "general quarters" is sounded, when the men of the two watch-standing sections off watch distribute themselves "in reserve," behind armor, as shown in the regular ship's bill. The men then stand watch and watch, relieving each other every four hours, even after "all hands" are at "general quarters," and until the action commences. Relief while the engagement is actually in progress is not contemplated.

At the call for "general quarters" take stations for full-power steaming, if not having already done so. The special work to be done by the various squads, under the direction of the officers in charge of station and squad leaders, is specified below.

Men having coal-passer numbers in the first and third sections go to powder division when off watch.

Fireroom Squads—First, Second and Third Stations.—If ordered to be ready for steaming at full power, get boilers ready, blowers started, feed and fire pumps warmed up, tested and run at the speed necessary to give the required pressures. Station men at telephones and speaking tubes in each compartment, and inquire as to disposition to be made of machinery and boilers; turn steam off all lines above protective deck, ash-hoist engines, whistle, siren, galley, scullery and pantry, ice-making machines, evaporators and heaters, obtaining permission to do so first. Be ready to cut out all risers of fire mains and flushing system when ordered. Close all watertight doors and hatches, then open such as may be actually needed at the time. Connect up fire hose and nozzles, light oil lamps or storage-battery lights, and fit in place.

Secure everything movable to prevent injury by shock. Get supply of drinking water, and distribute one "first-aid" package in each fireroom. Eject ashes; have matches and special fire extinguishers ready. Carry out provisions for collision drill.

Fireroom Mechanics—Fourth Station.—Stand watch with their regular sections on the blowers, and all must be ready to answer a call in the firerooms.

Engine-room Squad—Fifth and Sixth Stations.—The senior officer or petty officer in each engine room will start pumps on fire mains and regulate their speed to maintain required pressure; turn steam off all steam lines above protective deck, including steam to heaters and pantries; connect up hose and nozzles; start air compressors on gas-ejecting system; provide storage-battery or oil lamps trimmed and lighted, and hand them in place. Fit battle bars in place as soon as all hands are below, and close all watertight doors and hatches. Make necessary preparations for getting underway or for steaming at full power. Be ready to close risers to fire main and flushing system. Turn steam on any lines above protective deck to start machinery only on orders from engineer officer. Have drinking water ready and "first aid" packages in each engine room.

The speed of pumps in fire and engine rooms will be regulated by direction of the officer on duty so as to maintain required pressures. Station men at voice tubes and telephones in each engine room; start up all air compressors and put pressure on gas-ejecting system. See all tools, spare parts and movable articles securely in place, to avoid damage by displacement from shock or ramming. If orders are received to prepare for ramming, open drains on separators and traps to prevent passage of water from boilers to engines. Be ready to carry out all provisions as for collision drill.

Shop Squads—Seventh Station.—Assemble in the machine shop; close watertight doors and battle hatches and fit special operating wrenches on station. Provide tools and gear for emergency repairs. See that the covers of engine-room

hatches, dampers in sides opened and hoods put over vents of the fuel-oil tanks. Man the speaking tubes and telephones and be prepared to act as a repair party wherever called. Have lamps lighted, candles and matches at hand, and patent fire extinguishers ready.

Auxiliary Machinery Squads—Eighth Station.—Men on watch remain on watch or secure machinery, as ordered, and remain on post. Chief machinist mates stand watch in engine rooms with their regular stations. Men on watch remain on watch on ice machines and evaporators, or secure machinery, as ordered. Fit in place and be prepared to operate any special safety gear for working drain valves, cut-outs, etc. Remain on station unless ordered elsewhere.

Men off watch report to office for special detail.

Dynamo men go to dynamo rooms.

Special Station—Ninth Station.—Washroom keepers, mess men, compartment and passageway cleaners will remain on their stations. Ship and stand by to operate all wrenches for special safety gear, such as safety valves, drain cut-outs, watertight doors, bunker flood cocks, fuel-oil cut-outs, steam-line cut-outs. Close valves in bunker vents, which must be opened at "Secure."

The officer of the auxiliary and special stations will superintend this work and make the individual details. Men will be instructed not to operate any of the gear without specific orders, unless absolutely necessary.

Supernumeraries report to office for special detail.

Office Force and Storeroom Keepers—Tenth Station.—Go to their stations. The officer in charge of personnel will detail men to fill vacancies on various stations.

The Ammunition Party.—All coal passers, or men having coal-passer numbers in the first and third sections of watch standers are detailed to assist with the ammunition supply.

As these men are never on watch at the same time, the ship's ammunition passers will always be reinforced by one section of coal passers. These men will go to the places assigned for drill.

FIRE QUARTERS.

Any person discovering fire on board ship shall immediately endeavor to extinguish or control it with the means at hand, and shall quietly report or send message to the officer of the deck as quickly as possible, stating the location and extent of the fire, as far as known. Any person noticing the odor of burning rubber shall notify the dynamo room through the officer of the deck.

At the sounding of the alarm the first thing to be done by the watch, whether in port or at sea, is to put all fire and bilge pumps on the fire main, and regulate the pressure by directions of the senior person in the engine room. Care should be taken to prevent excessive pressure on fire main by opening overboard discharge valves or slowing down pumps, if necessary.

All officers and men go to their stations quickly and quietly, and perform the various duties enumerated below, reporting their stations to the engine room when ready. *At night* men take one turn around their hammocks and hang them up by the head and foot rings on one hook clear of the passageway, then go to their stations.

To prevent unnecessary crowding or confusion in the engine and firerooms, at sea the first relief section only will go below; the other sections of the steaming watches off watch will fall in at regular quarters for muster, but men already below on their stations remain there.

All men of berth deck and auxiliary stations go to their regular stations.

The following duties will be performed on all stations:

Shut down all ventilating blowers.

Connect up hose and stand by it, but do not lead it out if it will not reach the vicinity of the fire, unless ordered to. Fire hose will be carefully handled to prevent injury to couplings, abrasion or soiling of hose.

Stand by all watertight doors and hatches, and be ready to close them. These are closed to prevent air drafts reaching

the scene of the fire, but passageways should not be blocked off by closing doors unless specially ordered to do so.

Close all air ports in the department.

Close valves in bunker and fuel-oil vents or place covers on them. These will be opened again at "Secure."

Stand by to put the distiller circulating pump on fire main if ordered.

Stand by steam and water connections to fuel-oil tanks or bunkers.

At "Secure," everything is secured, stations reported to the engine room. Men will remain on the stations or at quarters until dismissed at "Pipe down."

COLLISION QUARTERS.

At the signal for "Collision Quarters" men go to their stations as at Fire Quarters. Men on watch or at work below remain there, and, reinforced by the "First Relief Section," carry out the duties specified below. Other sections fall in as at quarters for muster.

Fires will be started, if necessary, and preparations will be made for getting underway, if at anchor. All fire and bilge pumps will be started, and proper connections made for pumping water out of compartments. The main circulating pumps will be put on the main drains. Compartments will be sounded, and men stationed by main valve stems on berth deck, removing plates and shipping wrenches. All watertight doors and hatches will be closed, and none opened thereafter without permission of the engineer officer.

Prepare to localize the injury by shoring up bulkheads of flooded compartment and stopping leaks into adjacent compartments and keeping them drained. All strainers for all suctions should be clear and all valves closed. Be ready to correct serious list or trim by transfer of fuel oil or feed water to opposite side of the vessel, but the equalizing pipes between compartments should be closed before transfer of water.

If the compartments become flooded men will pass up through the escape hatches or hatches specially designated. Men will not leave the compartments until ordered. In case of abandon ship, fires will be hauled, and steam shut off main engines before leaving compartments.

The shop squads form repair party in shop, providing the necessary tools.

Officers and petty officers report their various stations when ready and when secured to the engine room. Men do not leave their stations until "Pipe down," or unless ordered to abandon ship.

ABANDON SHIP.

At the order to "Abandon ship" the entire division quietly falls in by sections under the section officers, abreast the boats assigned by the ship's bill. The men are not individually detailed to boats, but the officers in charge of sections will detail the required number of men to each boat in accordance with the ship's organization, and no one will leave the ranks unless ordered to do so by his section officer.

For drill, men actually on watch will not leave their stations.

Before leaving station for "Abandon ship," haul fires and turn steam off main engines.

IRON CARBON ALLOYS.*

COMPILED BY LIEUT. G. J. MEYERS, U. S. N., MEMBER.

The chemical study of iron and steel has established the fact that carbon exists in steel or in cast-iron in three different forms: (1) graphite, (2) "carbide carbon," (3) "hardening carbon." Graphite is identical with natural graphite. "Carbide carbon" corresponds to a carbide which is known to have the composition Fe_3C. "Hardening carbon" is carbon in a state of solid solution.

The generally accepted hypothesis of iron is that it may exist in three allotropic modifications; that is, iron exists in three forms as iron, but each form has different physical properties. The first form is called gamma-iron which forms when the metal starts to freeze from the molten state and has considerable solvent power for carbon and is the only modification capable of forming concentrated solid solutions. At about 900 degrees C. it passes into the second form, called beta-iron, the change being accompanied by a development of heat, and by considerable expansion of volume. At about 760 degrees C. beta-iron changes into the third modification, called alpha-iron, with development of heat but very little alteration of volume. It is not certain whether beta-iron has the property of retaining carbon in solid solution.

The solubility of carbon in alpha-iron must be very small, not exceeding 0.05 per cent. The terms gamma, beta and alpha-iron are applied to iron only in its different physical modifications.

As gamma-iron is capable of forming solid solutions with carbon, which become hard under certain conditions of cooling, it forms with the carbon in solid solutions a hard variety of steel. It is the only modification which when cooled

(* Photomicrographs furnished by the Crane Co., Chicago.)

rapidly forms with carbon in solid solution a hard alloy of iron and carbon.

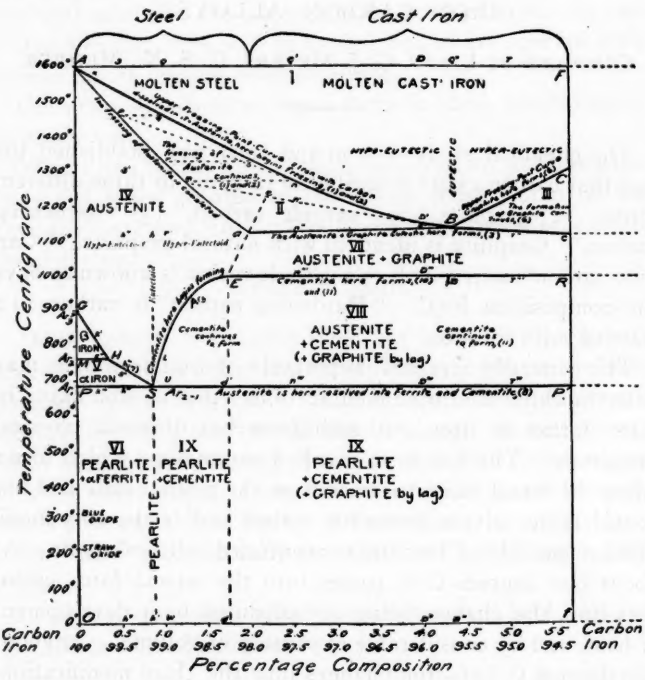


FIG. 1.

Referring to the diagram of iron and carbon, Figure 1, the freezing point of iron is depressed by carbon, the curve having the form indicated. A eutectic point is reached at 4.3 per cent. carbon and 1,125 degrees C.; that is, this point indicates that 4.3 per cent. of carbon in iron forms an alloy which has the lowest melting point of all alloys of iron and carbon.

Steel and cast-iron consist of different alloys of carbon and iron. The forms of carbon in steel and iron have already been given. Iron is present in steel and cast-iron in the form of ferrite and cementite. A further discussion will show that they do not exist free together in the iron-carbon alloys.

Ferrite is a pure (or nearly pure) metallic iron which is soft, weak, very ductile, with high electric conductivity, and in general like copper in its qualities, color excepted.

Cementite is a definite iron carbide, Fe_3C, which is harder than glass and nearly as brittle, but probably very strong under gradually and axially applied stress.

The properties of several classes of iron and steel may be influenced, and very profoundly, by thermal and mechanical treatment and by the presence in certain of them of slag or of graphite; but the fact remains that the differences in properties between the different industrial classes of iron and steel are due chiefly to differences in the ratio which the ferrite bears to the cementite.

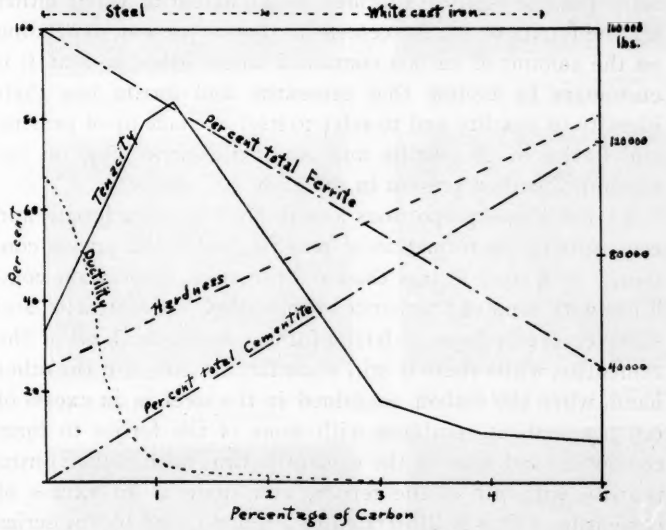


FIG. 2.

Naturally as the proportion of cementite in steel increases, and that of ferrite decreases, the ductility diminishes continuously and the hardness increases continuously; the tensile strength, however, reaches a maximum when the cementite amounts to about 15 per cent. of the whole and the ferrite to

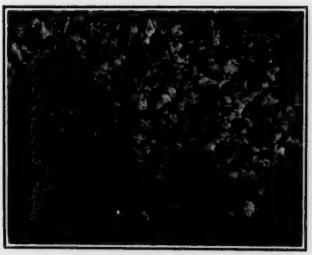
about 85 per cent.; with further increase of cementite the tensile strength again decreases. This is illustrated in Figure 2.

The ferrite and cementite in steel may be free (that is, may be free alone but not together) or may form very thin layers with each other. This statified structure is known as pearlite. Pearlite also exists in the form of a series of globules resembling strings of beads. Pearlite is made up of about six parts by weight of ferrite to one part by weight of cementite. The exact proportion is still in dispute. Pearlite contains about 0.9 per cent. of carbon in the combined state, so that steel containing about 0.9 per cent. of carbon is almost wholly pearlite. When steel or iron contains carbon in the combined state, pearlite is always formed to the extent of using either all the ferrite or all the cementite that is present, depending on the amount of carbon contained in the alloy, so that it is customary to assume that cementite and ferrite lose their identity in pearlite and to refer to steel as made up of pearlite and ferrite or of pearlite and cementite, depending on the amount of carbon present in the alloy.

As the above proportions nearly hold between ferrite and cementite in the formation of pearlite, and if the carbon contained in a steel is less than 0.9 per cent., the carbon combines with some of the ferrite to form Fe_3C, or cementite, and some of the remaining ferrite forms pearlite with all of the cementite, while there is still some free ferrite. On the other hand, when the carbon contained in the steel is in excess of 0.9 per cent., it combines with some of the ferrite to form cementite, and some of the cementite thus formed then forms pearlite with all of the ferrite, and there is an excess of cementite. This is illustrated by Figure 3, and by the series of photomicrograph Numbers I to XIII, inclusive.

No. I is American ingot iron of 99.65+ per cent. of ferrite. The light, granular spots are ferrite, the dark lines surrounding them are boundary lines between adjacent grains of ferrite. When a polished surface of the metal is etched the acid, of course, eats the corners of the cube faster than the surface, and the lines etched down between the grain, not giving a

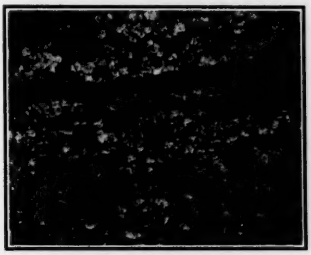
I.—American Ingot Iron — 99.5 + Per Cent.



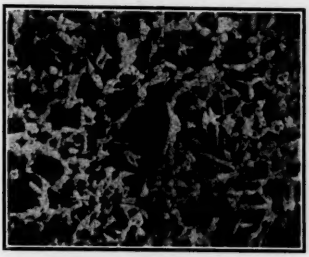
V.—0.30 Per Cent. Carbon Steel.

II.—Common Sheet Steel, Practically No Carbon.

VI.—Steel as Cast — 0.30 Per Cent. Carbon.



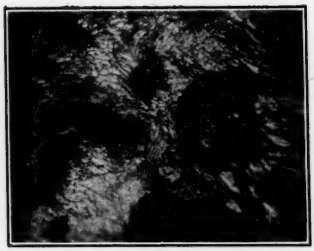
III.—Commercial Wrought Iron—Longitudinal Section.



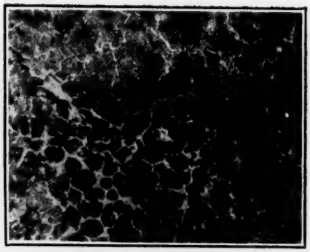
VII.—0.50 Per Cent. Carbon Steel.

IV.—0.10 Per Cent. Carbon Steel.

VIII.—0.86 Per Cent. Carbon Steel as Cast.

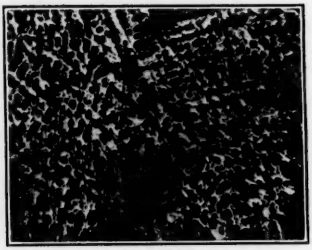


IX.—0.86 Per Cent. Carbon Steel—Pearlite.

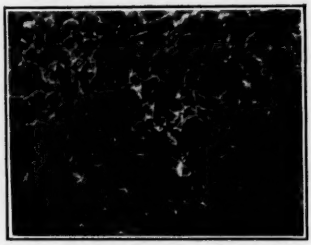


XII.—2.0 Per Cent. Carbon Steel—Carbon all Combined—As Cast.

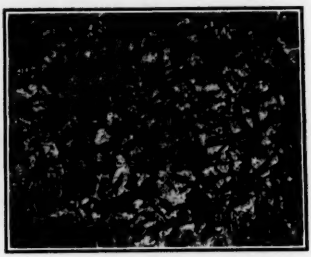
X.—1.25 Per Cent. Carbon Steel.



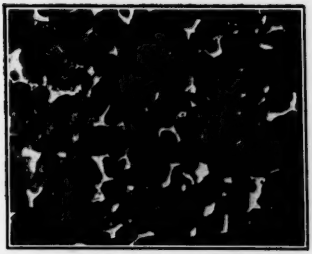
XIII.—White Cast Iron—Carbon 3½ Per Cent.



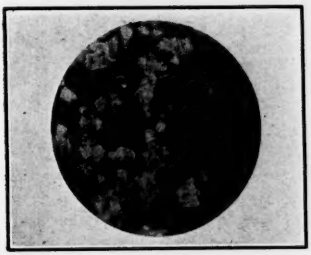
XI.—2.0 Per Cent. Carbon Steel—Carbon all Combined.



XIV.—Soft Cast Iron—Combined Carbon 0.10 Per Cent.—Graphitic Carbon 3.2 Per Cent.

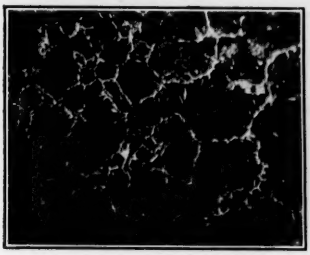


XV.—Medium Cast Iron—Combined Carbon 0.4 Per Cent—Graphitic Carbon 2.9 Per Cent.



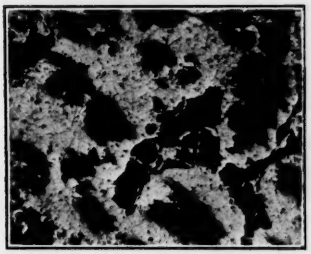
XVa.—Manganese Steel, Quenched in Water from 1200° C.—Showing Structure of Austentite.

XVI.—0.5 Per Cent. Carbon Steel, Quenched from 850° C.—Austentite.

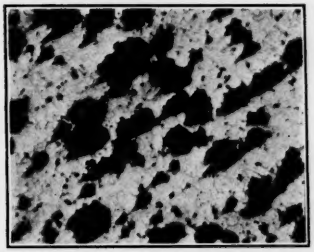


XVII.—0.5 Per Cent. Carbon Steel, Cooled from 1000° C.

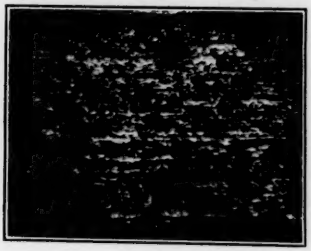
XVIII.—Cast Iron—3¼ Per Cent. Carbon—Annealing Just Begun.



XIX.—Cast Iron—3¼ Per Cent. Carbon—Annealing Nearly Complete.

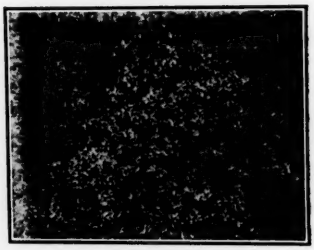


XX.—Cast Iron—3¼ Per Cent. Carbon—Annealing Complete.

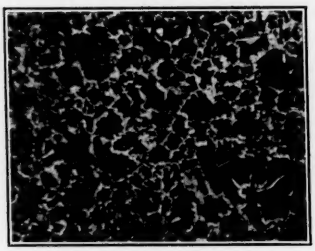


XXI.—0.3 Per Cent. Carbon Steel—Cold-Drawn Steel Wire.

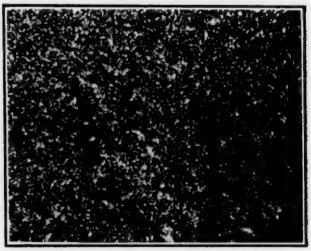
XXIa.—0,3 Per Cent. Carbon Steel —Drawn and Annealed.



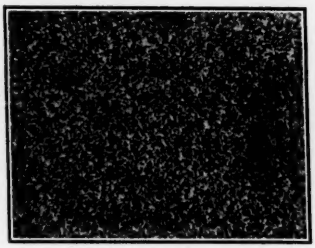
XXIV.—0.3 Per Cent. Carbon Steel —Forged Hot.



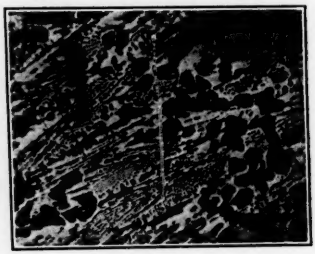
XXII.—0,5 Per Cent. Carbon Steel —Annealed at 1000° C. and Cooled too Slowly.



XXV.—0.3 Per Cent. Carbon Steel —Forged and Annealed.



XXIII.—0.5 Per Cent. Carbon Steel —Annealed at 780° C. and Cooled in Air.



XXVI.—Manganese Pig Iron—7 Per Cent. Iron.

horizontal surface, do not reflect the light up through the microscope as do the flat surfaces of the grains. Hence the junction lines appear dark and the surface of the grains bright.

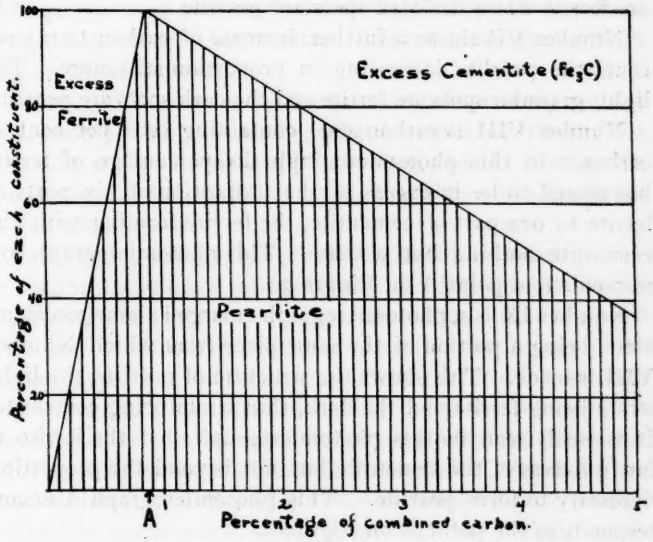


FIG. 3.

No. II is common sheet steel of practically no carbon. The granular spots are ferrite, the dark lines surrounding them are boundary lines between adjacent grains of ferrite.

No. III is commercial wrought-iron, longitudinal section. The granular spots are ferrite, while the dark, fine lines are boundary lines between adjacent grains of metal, and the dark streaks are slag.

No. IV is carbon steel containing 0.1 per cent. of carbon. Here the ferrite is still in excess. The carbon has combined with some of the ferrite to form cementite, while all of the cementite in turn has formed pearlite with some of the remaining ferrite. The light, granular spots show the ferrite, while the dark spots show the pearlite.

Numbers V and VI are carbon steel containing 0.3 per cent. of carbon. Number V is rolled steel while Number VI is

steel as cast. Both, however, show the proportion of pearlite increasing, due to the fact that there is more carbon to form cementite and hence more cementite to form pearlite, leaving a smaller proportion of free ferrite. The light, granular spots are ferrite while the dark spots are pearlite.

Number VII shows a further increase of carbon to 0.5 per cent., the pearlite increasing in proportion still more. The light, granular spots are ferrite and the dark spots are pearlite.

Number VIII is carbon steel containing 0.86 per cent. of carbon. In this photomicrograph the percentage of ferrite has ceased to be in excess of the proportion of six parts of ferrite to one part of cementite, the ferrite forming with the cementite nothing but pearlite. This photomicrograph corresponds to a point A on Figure 3.

Number IX is a photomicrograph enlarged about 300 diameters, being a portion of the same piece from which Number VIII is made. This shows the structure of pearlite, the light strata being ferrite and the dark, thin strata being cementite. It is easily seen in this photomicrograph that the ferrite is far in excess of the cementite but not beyond the proportion necessary to form pearlite. This photomicrograph also corresponds to the point A on Figure 3.

Number X is a photomicrograph of a piece of carbon steel containing 1.25 per cent. It will be seen in this photomicrograph that the per cent. of cementite is greater than that necessary to form nothing but pearlite. There is more carbon to combine with ferrite to form cementite, and not enough ferrite left to form pearlite with all of the cementite thus formed. The dark, granular spots are pearlite and the thin, white lines surrounding them are cementite.

Numbers XI and XII show a still further increase of carbon to 2 per cent. all combined. There is consequently an increase in percentage of cementite shown by the white lines while the dark is pearlite.

Number XIII shows white cast-iron with a total of 3.5 per cent. carbon. In this photomicrograph the dark spots represent pearlite while the white spots represent cementite, which is in much greater percentage than in Numbers XI and XII.

Number XIV shows a cast-iron containing 0.1 per cent. combined carbon and 3.2 per cent. graphitic carbon. The graphitic carbon is shown by the thin, long streaks, the ferrite by the light spots, and pearlite by the dark, globular spots. The light spots are practically pure iron. The graphitic carbon is uncombined, and by forming lines of cleavage tends to weaken the structure.

Number XV shows a medium cast-iron containing 0.4 per cent. combined carbon and 2.9 per cent. graphitic carbon. The graphitic carbon is shown by the long, black streaks, the pearlite by the dark portion surrounding them, and the ferrite by the white spots.

"Hardening carbon," as previously stated, is carbon present in steel in the state of solid solution. As the iron-carbon alloy cools slowly from the molten state this carbon either combines with ferrite to form cementite or separates out into graphitic carbon, depending on the amount of carbon the alloy contains. But when the alloy is cooled rapidly the carbon remains to a certain extent in solid solution, forming with the ferrite and with any cementite that may have formed a very dense and hard structure. If the alloy could be cooled rapidly enough all of the gamma-iron would form with the carbon a solid solution which is known as austentite. However, it has not been found possible to prepare pure austentite by quenching a pure iron-carbon alloy because we cannot quench or cool fast enough, though by the use of liquid air and by the aid of the restraining influence of manganese or nickel we can approximate it, and obtain considerable austentite. This is shown in Number XV, a photomicrograph of manganese steel quenched in water from 1,200 degrees C.

In the ordinary quenching experiments one obtains a mixture of austentite with ferrite and cementite in a very finely-divided form. Several of the stages in the resolution of the solid solution lead to the production of such characteristic microscopic structures that distinct metallographic names have been given them. The stages generally recognized are: austentite, martensite, troosite, sorbite, pearlite.

Martensite is the principal constituent of iron-carbon alloys hardened by a rapid quenching. It is the essential constituent of hard steels, and is the cause of their hardness. It represents the first stage in the resolution of austentite during cooling into iron and cementite. If from about 780 degrees C. or higher steel is suddenly cooled, the carbon and iron have no chance to crystallize out as pearlite, but supposedly remain in about the condition they were before quenching. Number XVI is a photomicrograph illustrating the appearance of martensite. This was taken from a 0.5 per cent. carbon steel quenched from 850 degrees C. and is here magnified to about 300 diameters.

Troosite is a constituent of hardened steels especially after partial tempering. The physical and chemical properties of troosite all indicate that it is a mixture of cementite and ferrite, only differing from pearlite in its extremely fine state of division.

Sorbite differs only in its minutely-granular structure from pearlite. A photomicrograph reveals nothing essentially different from pearlite except a finely granular structure. Number XVII shows sorbite surrounded by light lines indicating ferrite. (Compare with Number VIII.) This is a 0.5 per cent. carbon steel cooled rapidly from 1,000 degrees C. It is harder than pearlite, but not as ductile, and has not been cooled rapidly enough to make it remain in the form of martensite.

The other thermal treatment of iron and steel is annealing. Annealing is heating to a high temperature and cooling slowly. In this treatment all unequal strains are removed from the material, and the molecules of iron and carbon have a chance to reach a state of equilibrium which does not exist in quenched steels.

The adjustment is well illustrated in the process of treating malleable cast-iron. This is illustrated in photomicrographs Numbers XIII, XVIII, XIX and XX. Number XIII shows the white cast-iron before annealing. Number XVIII shows the process of annealing just begun. The cementite is probably just decomposed into pearlite and then into ferrite and

amorphous carbon, which latter collects in the mass in the form of globules. Number XVIII shows these black spots of amorphous carbon, the white surrounding them being ferrite, the remainder pearlite. Number XIX shows the process nearly completed. The cementite and pearlite have broken up into ferrite and carbon, the black spots being carbon and the light spots ferrite. Number XX shows the process completed. The original structure has changed to amorphous carbon (black) and ferrite (white).

The effect of proper annealing on steel is to reduce the size of the grains. This is illustrated on photomicrographs numbers XXI, XXIa, XXII and XXIII. Number XXI is a longitudinal section of a piece of cold-drawn steel wire of 0.3 per cent. carbon. This shows distortion due to working at too low a temperature. This distortion is corrected by proper annealing, as is shown by Number XXIa. Numbers XXII and XXIII are photomicrographs showing the annealing of the same piece illustrated by number VII—0.5 per cent. carbon steel. Number XXII is too slowly cooled from an annealing temperature of 1,000 degrees C., which is too high for proper results. The resulting crystals with too high a temperature and cooling too slowly are too large. Number XXIII shows proper annealing of the same piece (Number VII) from 780 degrees C. and cooled fairly rapidly in air. The resulting crystals are very small and form a denser structure.

Number XXIV shows a piece of 0.3 per cent. carbon steel forged hot. Forging done at proper temperature adds to fineness of grain and improves the physical properties.

Number XXV shows a piece 0.3 per cent. carbon steel forged and properly annealed. This process produces still finer grains and still further improves the physical properties.

The effect of manganese on iron-carbon alloys is to prevent segregation of the carbon in the graphitic form. This is illustrated in number XXVI in the case of manganese pig iron containing 7 per cent. manganese. The black spots represent pearlite and the white spots cementite containing manganese.

TEST OF NEWPORT NEWS WATER-TUBE BOILER.

By F. P. Palen, Associate.*

There has been developed at the works of the Newport News Shipbuilding and Dry Dock Company a marine water-tube boiler of the ordinary three-drum type, consisting of an upper steam drum and two lower water drums, connected by nests of tubes. For the purpose of testing the efficiency of this design an experimental boiler was built and installed in the power plant at the works of the Newport News Shipbuilding and Dry Dock Company in the fall of 1912.

Certain special features have been adopted in the design which give the boiler a high efficiency and which overcome objections that have been brought forward against the use of water-tube boilers for marine work, especially for the merchant service. The design of the boiler is shown on Plates 1 and 2. The experimental boiler, under construction, is shown on Plates 3 and 4, and the completed boiler on Plate 5.

The boiler, as will be seen from the drawings and photographs, is constructed with large drums so as to give it a large water capacity. The large water capacity very much lessens the attention required on the part of the water tender and the liability of accidents from low water. The large steam drum also provides a greater surface area of the water for the liberation of steam and a much larger steam space. The large steam space is especially desirable in marine boilers when the vessel is rolling or pitching in rough weather.

The tubes are designed so that they can be removed by drawing into the steam drum. The curvature of the tubes is

---

* Assistant General Manager Newport News Shipbuilding Company.

such as to enable them to be drawn into the steam drum across the diameter, as shown in the dotted lines on Plate 1. In the experimental boiler already constructed tubes have been removed and replaced without any difficulty. In order to facilitate the drawing of the tubes into the drum the holes in the upper steam drum are drilled larger than the tubes and the tubes rolled out to fill the hole.

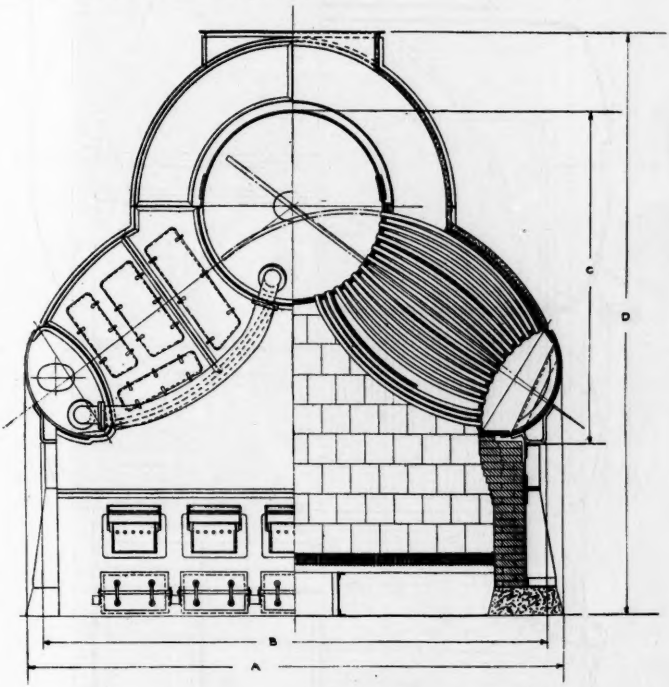


PLATE 1.—CROSS SECTION OF BOILER.

The tube nests are arranged with a large number of tubes in the vertical rows so that baffle plates can be installed, with sufficient area between the baffle plates for the passage of the gases of combustion. The proper arrangement of the baffle plates is of the greatest importance as affecting boiler efficiency, and the arrangement adopted in this boiler is made practicable

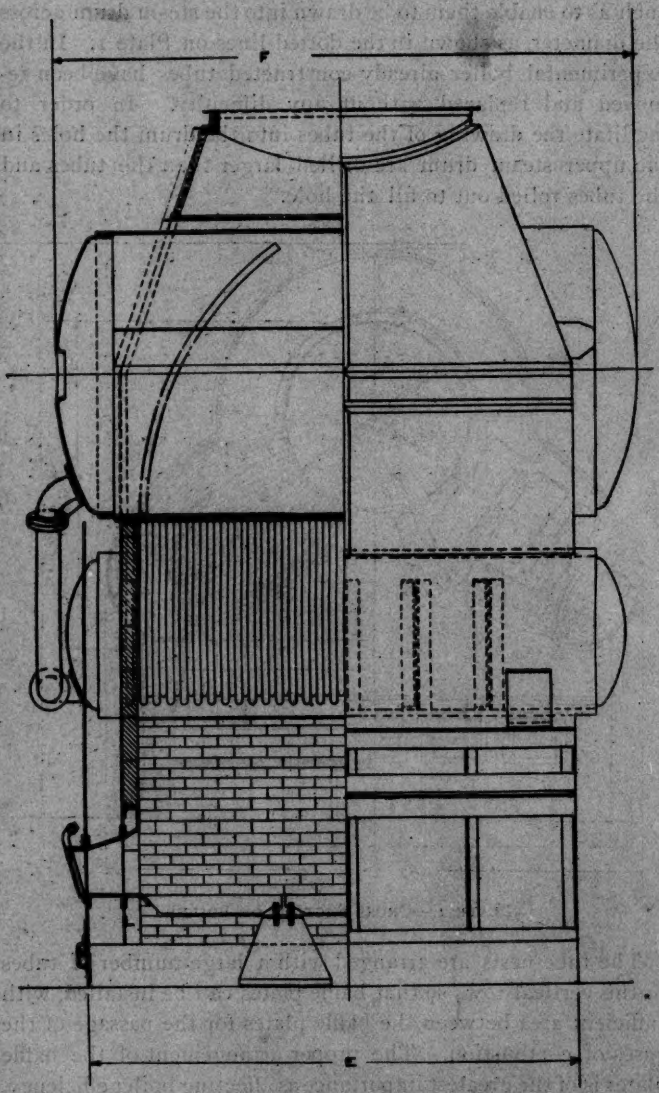
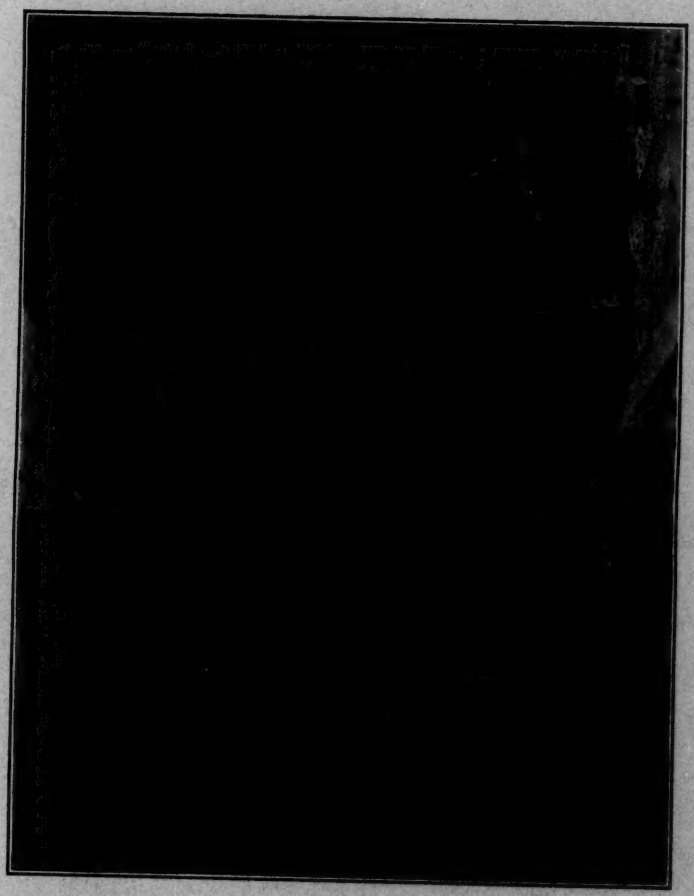
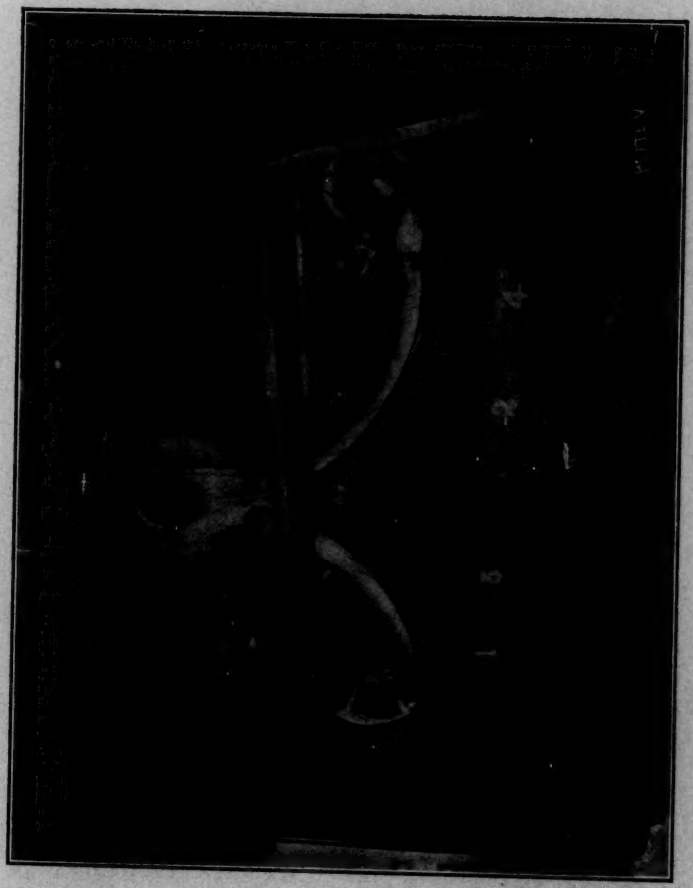


PLATE 2.—LONGITUDINAL SECTION OF BOILER.





by the wide tube nests. The wide tube nests made it feasible to shorten the tubes so they can be drawn into the steam drum as above noted, and at the same time give the required amount of heating surface in the boiler.

The evaporation tests have shown that the baffling has a great influence upon the circulation of the water in the boiler and therefore upon the efficiency. The conclusions indicate that the baffles should be arranged so the lower tubes in the tube nest are the hottest and the upper tubes the coldest, and that the lower tubes next to the furnace should be heated the hottest at the lower end next to the water drum. It is probable that the circulation takes place in an up-current through the tubes next to the fire, and that this circulation is assisted by heating these tubes the hottest at the lower end, so that the steam will pass up through the tubes into the steam drum. On the other hand, if the tubes are heated at the upper end it probably retards the up-circulation in them.

The lower drums are stayed by heavy angles riveted to the outer plate about two feet apart with a brace connecting the ends of the angles. These stiffeners are shown on Plates 1 and 2. This stiffening holds the lower plate in shape and keeps heavy strains from coming on the flanged corner of the tube sheets. The drums were tested by hydraulic pressure, before the holes for the tubes were drilled in the tube sheet, and no distortion of the lower sheet was noticeable. The large lower drums allow sufficient room for the installation of this stiffening and for easy access to the drums.

The large upper drum is clear inside except for the dry pipe and feed pipes, and affords ample room for withdrawing the tubes and for cleaning and examining the inside surface of the tubes.

The special features which make the boiler well adapted to marine work for both naval and merchant service, in summary are as follows:

1. Large water capacity and steady water level without the necessity of automatic feed regulators.

2. Large steam spaces.

3. Large combustion chambers with consequent good combustion.

4. Short tubes that can be removed and replaced through the steam drum.

5. Accessibility of tubes for cleaning both on the inside and outside.

6. Good circulation.

7. Steam can be raised to full pressure in 30 minutes without injury to boiler.

8. Boiler can be built or repaired in any ordinary boiler shop without special equipment.

9. Slight danger of explosion from low water.

10. No stayed flat surfaces on which grease can collect and cause explosion.

11. Boiler can be fired and operated by unskilled firemen.

12. Weight of boiler wet approximately one-half of ordinary Scotch boiler.

13. Simple arrangement of baffle plates, which gives long passage for gases of combustion, resulting in high efficiency.

14. Less expansion on account of the short tubes, and therefore less tendency to leak from expansion strains.

15. The curvature of the tubes next to the fire allows them to bend and thereby provides for the expansion due to the higher temperature of these tubes.

16. Very few riveted joints.

17. Very few handhole or manhole covers.

The test boiler was completed in the fall of 1912, and has been in service in the power plant of the Newport News Shipbuilding and Dry Dock Company for nearly two years. On account of heavy demands for power during this time, it has not been practicable to put the boiler under test until this summer. The engineering staff of the company conducted a series of evaporation tests in July, and the high efficiency of the boiler indicated the advisability of having these tests carefully gone over by other engineers. Arrangements were, therefore, made with Mr. A. T. Baldwin, President of the Precision Instrument Company of Detroit, Michigan, to con-

duct a series of evaporation tests on the boiler. Mr. Baldwin, assisted by Mr. L. C. Rogers, of Detroit, tested the boiler on July 23–30, 1914. The boiler was operated during the test by the regular power-house fireroom crew. The boiler operated under natural draft, and evaporation tests burning 15, 20 and 25 pounds of coal per square foot of grate surface were run. The 15-pound test was the first run, and I think the results of this test can be improved by repeating it, due to the experience of the subsequent test.

Mr. Baldwin's report follows:

"Detroit, Michigan, Sept. 5th, 1914.

"Acting on your request of July, 1914, to make a series of tests on the Newport News type boiler, located at the plant of the Newport News Shipbuilding and Dry Dock Co., I take pleasure in presenting herewith the data.

"*Location of Boiler.*

"The boiler was located at the general power plant of the above-mentioned company, in a separate building, but with the breeches connection at a point in the main flue between the main 220-foot stack and the main battery of boilers. Due to this location there was a certain effect in the operation of the boiler being tested that made it necessary to control very carefully the operating conditions, due to the stopping and starting of the boilers in the main battery. It also prevented the collection of the floury matter passing out with the escaping gases. The steam developed was delivered to the main steam line.

"*The Purpose of the Tests.*

"The tests were made for the purpose of determining its efficiency and checking former tests made by the above company.

"*Manner of Conducting Tests.*

"The tests were conducted in accordance with the code adopted by the A. S. M. E. The 'alternate' method being used in starting and stopping. In order to avoid interrupting

'test conditions' the cleaning of fires was confined to the removal of large clinker which failed to pass through the ½-inch air spaces in the grates. At the end of each test the ash and refuse was carefully weighed and a correction made in the gross weight for moisture in ash resulting from quenching.

"*Personnel.*

"The tests were carried on under the direct supervision of the writer and his associate, Mr. Louis C. Rogers, and a staff selected from the force of the Newport News Shipbuilding and Dry Dock Co.

"The taking of data was in charge of Mr. A. F. Schreiber, who divided the work into practically three shifts of three men each, one being made responsible on each shift. One was in charge of the weighing of coal and the general log of test, etc.; the second was in charge of the measurement of the feed water, taking temperatures, etc., and the third made and recorded the gas tests.

"The firing was handled by one (1) chief fireman, who worked throughout each entire run; two (2) door tenders, and four (4) coal passers who screened, weighed and delivered the coal according to the schedule; the shift of four (4) alternating every two hours.

"A boiler feed-pump man, who assisted the data man in changing water tanks and maintaining a uniform height of water in gage glass, completed the staff.

"The coal was checked by the chief fireman, and when changing water tank there was a man on each tank to throw valves and a third to read the water-tank gage level.

"*The Coal Used.*

"The coal used in Tests 1 and 3 was obtained from the Ballinger mine and was supposedly Nuttalburgh. As the coal cars were unmarked, this assumption may be in error. The coal used in Test No. 2 was New River red ash coal, car being marked from Lookout, West Virginia. Both coals were run-of-mine, and fine slack and pea was screened through a 1-

inch mesh screen in every case before the coal was weighed and fired. The coal used on Test No. 3 appeared to contain a good deal of slate. It will be noted that the percentage of ash and refuse in the case of Test No. 3 was less than the ash shown by chemical analysis. This is evidently due to the fact that a considerable portion of the light "floury" ash was carried along with the escaping gases and deposited upon tubes, baffles, flues, and at the base of and up the stack. As it was impossible to collect and weigh the ash thus lost, the 'combustible' was taken as the dry coal minus the dry ash and refuse obtained from the grates and ash pit at the end of each test. The complete analysis of the coal used on the tests is as follows:

"*Analyses of Coal and Ash From Tests.*

	Test No. 1.		Test No. 2.		Test No. 3.	
	Dry.	As rec'd.	Dry.	As rec'd.	Dry.	As rec'd.
Proximate analysis:						
Moisture	...	4.69	...	2.44	...	3.69
Volatile matter	25.13	23.95	24 93	24.32	24.01	23.12
Fixed carbon	69.52	66.26	68.73	67.05	66.98	64.51
Ash	5.35	5.10	6.34	6.19	9.01	8.68
Ultimate analysis:						
Carbon	81.63	77.80	81.85	79.85	80.28	77.32
Hydrogen	5.28	5.03	4.84	4.72	4.66	4.49
Oxygen (by dif.)	6.10	5.81	5.18	5.06	4.33	4.17
Nitrogen	0.99	0.95	1.07	1.04	1.04	1.00
Sulphur	0.65	0.62	0.72	0.70	0.68	0.65
Ash	5.75	5.10	6.34	6.19	9.01	8.68
Moisture	...	4.69	...	2.44	...	3.69
Calorific value:						
B.t.u.'s (gross)	14,666	13,979	14,342	13,993	13,999	13,482
Ashes:						
Carbon	24.62	23.59	20.61	20.22	27.44	26.39
Moisture	...	4.17	...	1.87	...	3.84

"Coal used on Tests 1 and 3 was Nuttalburgh coal from Ballinger mine. Coal used on Test 2 was New River red ash coal from Lookout, West Virginia.

"*The Firing of the Coal.*

"The firing force consisted of one chief, who timed the firing periods and directed where each shovelful should be placed, two firemen, who alternated each two hours, and a

door tender. The door tender closed the fire door momentarily after each shovelful.

"The firing was done at regular intervals. The plan consisted in firing an outside door on the right side first, then an inside door on the left side. The inside door on the right side was next fired, followed by the firing of the outside door on the left side; *i. e.*, the doors on the right side were numbered 1 and 3, while those on the left were numbered 2 and 4. The plan consisted in spreading the coal as evenly as possible with the least possible disturbance of the test conditions.

"Slicing was done when required, and large clinkers were removed twice during each test. The tubes were lanced before each test and thereafter as frequently as necessary as shown by the temperatures in the gas uptake at the damper. On the 15-pound test the lancing was not thoroughly done, as it was impossible to insert the lance in three of the holes drilled for this purpose. This fault was corrected.

"*Method of Obtaining Data.*

"The coal used was shoveled into a bucket and weighed on carefully-calibrated scales. A sample was taken from each bucket and kept in a covered can till the end of the test.

"The large sample (approximately 100 pounds) one from each test was carefully pulverized at the end of each test and quartered down to approximately 10 pounds. This sample was put in a tightly-sealed can and expressed to the laboratory in Detroit where the analyses were made. The ash sample was obtained in a similar manner. All samples were received in Detroit with seals unbroken.

"Inasmuch as the laboratory method of obtaining the moisture in the coal was superior to the usual plan of drying out a sample in a shallow pan placed above the boiler, the laboratory moisture figure is used in making calculations.

"The feed water was measured in two large rectangular tanks.

"At the conclusion of the tests the tanks were carefully calibrated by means of a standardized 66-gallon tank. The

test figures were carefully corrected in accordance with these calibrations.

"The quality of the steam was determined by means of a throttling calorimeter made of pipe fittings.

"The orifice in the instrument was ½-inch in diameter. A separating calorimeter was in use during a part of the first test, but this failed to collect any moisture whatever and the throttling calorimeter was substituted. It is possible that the data obtained from the throttling calorimeter is at fault and the true quality of the steam approximates 100 per cent. As a lower quality was used in accordance with throttling-calorimeter determinations, it is possible that evaporation and efficiency figures may be slightly lower than the true values.

"The draft was determined by means of Ellison inclined draft gages. The data obtained is of interest and is to be found below quoted in full.

"*Average Draft Obtained on Tests.*

Items.	Test No. 1.		Test No. 2.		Test No. 3.	
Normal rate of combustion	15 pds.	Dif.	20 pds.	Dif.	25 pds.	Dif.
Draft in ash pit, inch	.26	...	.24	...	.05	...
over fire, inch	.36	.10	.42	.18	.27	.22
at uptake, inch	.49	.13	.78	.26	.82	.55

"The very low draft shown in the ash pit during the 25-pound test was owing to the ash-pit doors being practically open during the entire test.

"*Average Temperature Readings.*

Items.	Test No. 1.	Test No. 2.	Test No. 3.
Normal rate of combustion, lbs.....	15	20	25
Outside air, degrees F.....	83	75	83
Boiler room, degrees F.....	95	88	96
Feed water entering boiler, degrees F.	103	99	101
Steam, degrees F	346	347	346
Throttling calorimeter, degrees F.....	264	261	265
Gases leaving boiler, degrees F.....	495	511	572

"As before noted, the 'combustible' is taken as dry coal minus dry ash and refuse. In calculating the calorific value of the combustible, the calorific value of the coal as fired is

divided by 100 per cent. minus the percentage of moisture and ash. This is best illustrated by the following table, viz:

"*Calorific Value of Combustible.*

Items.	Test No. 1.	Test No. 2.	Test No. 3.
Per cent. moisture as fired	4.69	2.44	3.69
ash as fired	5.10	6.19	8.68
moisture and ash as fired	9.79	8.63	12.37
combustible by dif. as fired	90.21	91.37	87.63
Calorific value as fired	13,979	13,993	13,482
of dry combustible	15,495	15,314	15,485

"The readings of the various instruments were taken each half hour. The tanks furnishing the feed water were read at the end of each hour, so that an accurate means of checking was furnished.

"*Gas Analysis.*

"This was taken regularly at half-hourly intervals, and the sampling was accomplished by the siphon-bottle method of drawing the sample from the flue, the sample for analysis being taken from the direct flow on the syphon connection. The sampling tube was very carefully placed in the main at a point centrally located relative to the flow of gas, and seemed to be about the correct position due to the analyses corresponding with the depth of fire and draft and the combustion being under good control by knowing the gas, the draft, and watching closely the depth of fire.

"DISCUSSION OF GENERAL RESULTS.

"The general data obtained is given in the accompanying table. It will be noted that the efficiency based on combustible is higher in the case of tests Nos. 1 and 2 than the efficiency based on dry coal. For test No. 3 the efficiency based on dry coal is higher than the efficiency based on combustible.

"These results are due to the fact that the percentage of ash and refuse in the case of Tests Nos. 1 and 2 was more and Test No. 3 was less than the percentage of ash shown by chemical analyses.

"The evaporative and efficiency figures obtained are good. Briefly the figures are as follows:

"*Evaporation and Efficiency Figures.*

	Test No. 1.	Test No. 2.	Test No. 3.
Normal rate of combustion	15	20	25
Equivalent evaporated from and at 212 degrees F. per pound dry coal, lbs.	10.990	11.112	10.867
Equivalent evaporated from and at 212 degrees F. per pound of combustible, pounds	11.837	11.929	11.615
Efficiency based on dry coal, per cent.	72.7	75.2	75.3
Efficiency based on combustion, per cent	74.1	75.6	75.3

Average efficiency for all tests based on dry coal, 74.4 per cent.
Average efficiency for all tests based on combustion, 74.3 per cent.

"The above efficiencies, while very good, would no doubt have been better throughout the series had the tubes been absolutely free from scale, and also due to the fact that the three lower rows of tubes below the first baffle were exposed to the gases of the combustion chamber, which fact necessarily produced CO on account of cooling effect of the tubes on the gases of combustion before they are completely converted.

"I am yours, very truly,

"ABRAM T. BALDWIN."

Table No. 1.

DATA AND RESULTS OF OFFICIAL TESTS NEWPORT NEWS TYPE WATER-TUBE BOILER.
NEWPORT NEWS, VIRGINIA.

Grate surface, 76.38 square feet.	Heating surface, 3,600 square feet.		
Normal rate of combustion in pounds per square foot of grate surface per hour	15	20	25
Date of test, 1914	July 23-24.	July 29-30.	July 27-28.
Weather	Pt. cloudy.	Pt. cloudy.	Pt. cloudy.
No. of test	1	2	3
Total quantities:			
1. Duration of test, hours	24	24	24
2. Weight of coal as fired, pounds	28,643	36,100	44,808
3. Per cent. of moisture in coal, p. ct.	4.69	2.44	3.69
4. Total weight of dry coal, pounds	27,300	35,219	43,155
5. Total ash and refuse, dry, lbs.	1,953	2,413	2,784
6. Per cent. of ash and refuse in dry coal, per cent	7.15	6.85	6.45

7. Total combustible, pounds	25,347	32,806	40,371
8. Total weight of feedwater, lbs	264,738	344,864	412,771
9. Water actually evaporated corrected for quality of steam, lbs	260,005	337,967	405,548
10. Equivalent from and at 212 degrees F., pounds	300,046	391,366	468,935
Hourly quantities:			
11. Coal consumed per hour as fired, pounds	1,193	1,504	1,867
12. Coal consumed per hour per square foot grate surface as fired, lbs	15.6	19.7	24.5
13. Ditto dry coal, pounds	15.2	19.2	23.9
14. Water per hour used, pounds	11,030	14,369	17,198
15. Water per hour corrected for quality, pounds	10,834	14,082	16,897
16. Water per hour from and at 212 degrees F., pounds	12,502	16,307	19,539
17. Water per hour from and at 212 degrees F., per square foot heating surface, pounds	3.5	4.5	5.4
Average pressures, temperatures, etc.:			
18. Steam pressure corrected by gage, pounds	114.3	113.1	114.4
19. Temperature of feed water, degrees, F	103	99	101
20. Temperature of exit gases at damper, degrees F	495	511	572
21. Suction in ash pit, in inches of water	.26	.24	.05
22. Suction over fires, ditto	.36	.42	.27
23. Suction at damper, ditto	.49	.78	.82
24. Quality of steam by throttling calorimeter, per cent	98.25	98.00	98.25
25. Absolute steam pressure, pounds	129.1	127.9	129.2
Economic results:			
26. Water evaporated per pound of dry coal, pounds	9.524	9.596	9.397
27 Equivalent evaporated from and at 212 degrees F. per pound dry coal, pounds	10.990	11.112	10.867
28. Equivalent evaporated from and at 212 degrees F. per pound of combustible burned, pounds	11.837	11.939	11.615
Efficiency:			
29. Calorific value of dry coal per lb. B.t.u.	14,666	14,342	13,999
30. Calorific value of combustible per pound, B.t.u.	15,495	15,314	15,385

31. Efficiency based on dry coal, p. ct.	72.7	75.2	75.3
32. Efficiency based on combustible, per cent	74.1	75.6	73.3
Gas analysis:			
33. Carbon dioxide (CO_2), per cent	11.42	11.36	12.20
34. Oxygen (O), per cent	7.29	7.44	6.52
35. Carbon monoxide (CO), per cent	0.57	0.53	0.87

Heat Balance, Referred to Combustible.

1. Heat absorbed by boiler (efficiency), per cent	74.1	75.6	73.3
2. Loss due to moisture in coal and to moisture formed by burning of hydrogen, per cent	4.4	3.97	4.1
3. Loss by heat of escaping gases, per cent	10.4	8.85	11.8
4. Loss by CO in gases, per cent	2.3	2.58	3.2
5. Loss by radiation carbon and other unconsumed combustibles in gases and unaccounted for, per cent	8.8	9.00	7.6
Total, per cent	100.0	100.00	100.0

Memoranda Regarding Test Boiler.

Total number of tubes	1,302
Outside diameter of tubes, inches	1¾
Average length of tubes, feet and inches	6-4.6
Number of rows high	20
tubes wide in 11 rows	33
in 9 rows	32
Horizontal pitch of tubes, inches	3¾
Area of heating surface below center of drum, square feet	3,600
Total heating surface, square feet	3,600
Length of grate, feet	6.5
Width of grate, feet	11.75
air spaces and bars in grate, inch	$\frac{7}{16}$ and $\frac{1}{8}$
Pitch of grate	Flat.
Area of grate surface, square feet	76.375
Grate to nearest tube, feet and inches, about	4-04
From upper drum to lower drum measured along center line, feet and inches	5-06½

	One side.	Two sides.
Area of opening past first flame plate, square feet	12	24
through first pass, square feet	13	26
past second frame plate, square feet.	8	16
through second pass, square feet	12.2	24.4
past third flame plate, square feet	6.22	12.44

	One side.	Two sides.
Area of opening through third pass, square feet.....	9	18
past outlet at center of last row tubes, square feet	2.67	5.34
past outlet at bricks, square feet.....	5	10
at uptakes, square feet.....	...	...
of heating surface (3 lower rows), square feet...	315	630
heating surface in first pass, square feet.....	529	1,058
heating surface in second pass, square feet....	501	1,002
heating surface in third pass, square feet.....	455	910

DESIGN OF A SMALL FOUNDRY CUPOLA.

By Lieut. F. M. Perkins, U. S. N., Member.

NECESSITY FOR A SMALL CUPOLA.

1. At the Puget Sound Navy Yard it was found that the considerable variation in the volume of foundry work interfered greatly with the economical operation of the cupola furnaces. There are three cupolas in the foundry, the smallest of which is lined to 24 inside diameter, and the one best suited in size to the melt for the day is used. In slack times, however, the smallest of the three cupolas is much too large to melt a day's work economically. It was very frequently the case that three or four days would elapse before there would be a sufficient number of molds ready to permit an economical melt of iron.

2. The result of this condition was, in slack times, that we were constantly choosing between two evils: either the jobs requiring iron castings were delayed for a period of one to four days in the foundry or the foundry was melting iron daily in a most extravagant manner. The latter course of action was more frequently decided upon in order to avoid delays in the machine shop and on the outside. The result was that the cost of melting iron was abnormally but unavoidably high.

3. The principal loss caused by operating a cupola at a small percentage of its normal capacity is in the excessive amount of coke used. This loss is largely due to the fact that the first charge of coke, the "bed," contains about five times as much coke as the other charges, and must be as large for a small melt of iron as for a large one. The cupola itself, which must be heated, will absorb an excessive amount of heat.

The waste of heat up to the stack is excessive; there is a long, blue flame extending from five to fifteen feet above the last charge of iron, the heat of which is entirely lost.

4. The 24-inch cupola before mentioned when operated under normal conditions will melt 6,000 pounds of iron with 825 pounds of coke. This gives a melting ratio of 7.27 pounds of iron per pound of coke. To melt 2,000 pounds of iron in the same cupola requires 425 pounds of coke, which gives a melting ratio of 4.71 pounds of iron per pound of coke. There is, therefore, a loss of 35 per cent. in efficiency when operating at one-third capacity. It has frequently been necessary to take down heats at about 1,200 to 1,500 pounds, in which case there is a loss of 48 per cent. in efficiency.

5. The necessity for melting iron in a cupola operating at a normal capacity is perfectly obvious when considered from the view point of fuel consumption. There are, however, other losses in addition to the fuel loss which greatly increase the need of using a cupola proportioned to the size of the melt. These losses include the increased labor and material required for patching up or "daubing" the lining after each heat and preparing the cupola for use. There is also a power loss due to operating a blower considerably below its rated capacity. There is a further loss due to the fact that the 24-inch cupola cannot melt less than about 1,000 pounds of iron with any assurance that the iron will be sufficiently hot to pour light work. Consequently, if only 500 pounds of iron castings, including gates and sprues, are to be made it is necessary to melt 1,000 pounds, and the melting loss (about five per cent.) is twice as great as it should be. The lost labor of charging and pouring off the extra 500 pounds adds further to the inefficiency of cupola operation under these conditions.

6. In order to eliminate these losses and to provide for a certain daily output of iron, no matter how few the orders for iron might be, it was decided to build a small cupola with a capacity of about 600 pounds. Such a cupola was designed by the writer and built in the yard largely from scrap ma-

terials, and is shown in the accompanying photographs. It has been in use about six months and has been so successful in fulfilling the purpose for which it was designed and also in several other ways that a description of the cupola may prove of some interest.

DESCRIPTION.

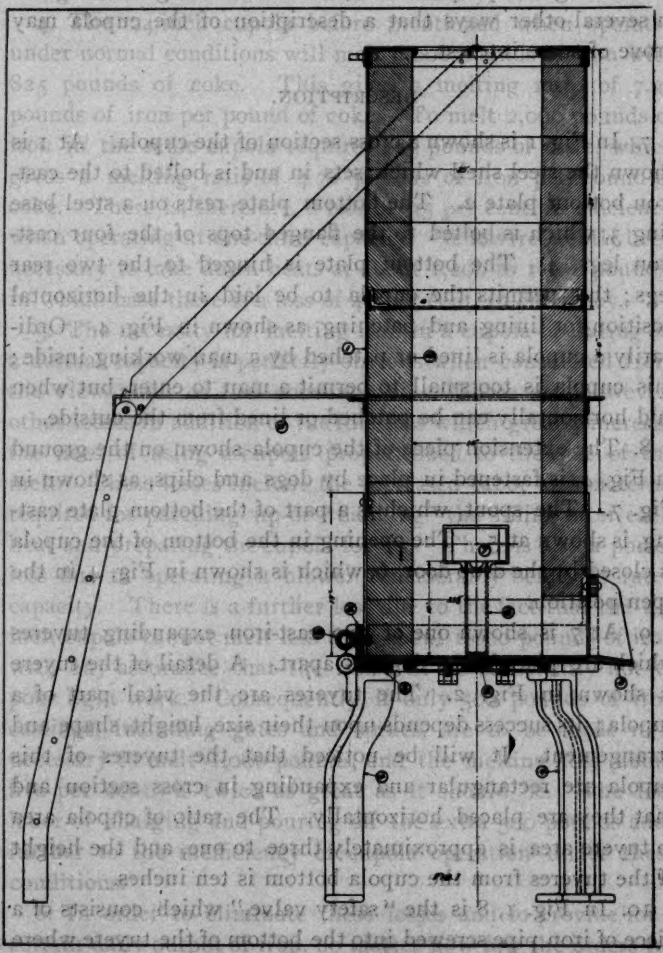
7. In Fig. 1 is shown a cross section of the cupola. At 1 is shown the steel shell which sets in and is bolted to the cast-iron bottom plate 2. The bottom plate rests on a steel base ring 3, which is bolted to the flanged tops of the four cast-iron legs, 4. The bottom plate is hinged to the two rear legs; this permits the cupola to be laid in the horizontal position for lining and patching, as shown in Fig. 4. Ordinarily a cupola is lined or patched by a man working inside; this cupola is too small to permit a man to enter, but when laid horizontally can be patched or lined from the outside.

8. The extension piece of the cupola shown on the ground in Fig. 4, is fastened in place by dogs and clips, as shown in Fig. 7. The spout, which is a part of the bottom plate casting, is shown at 5. The opening in the bottom of the cupola is closed by the drop door, 6, which is shown in Fig. 4, in the open position.

9. At 7 is shown one of two cast-iron expanding tuyeres which are placed 180 degrees apart. A detail of the tuyere is shown in Fig. 2. The tuyeres are the vital part of a cupola; its success depends upon their size, height, shape and arrangement. It will be noticed that the tuyeres of this cupola are rectangular and expanding in cross section and that they are placed horizontally. The ratio of cupola area to tuyere area is approximately three to one, and the height of the tuyeres from the cupola bottom is ten inches.

10. In Fig. 1, 8 is the "safety valve," which consists of a piece of iron pipe screwed into the bottom of the tuyere where the latter projects outside the cupola shell. The bottom of this pipe is closed with a white-metal fusible plug. If, through inattention on the part of the melter, the molten metal rises

above the bottom of the tuyeres, it will melt the plug and flow out the pipe, thus preventing damage to the wind box and connections.



11. The wind box or blast pipe is the connection between the air supply and the tuyeres. It is shown in detail in Fig. 3, and its location and the method of connecting to the cupola

can be seen in the photographs. It is a single iron casting with the least possible number of joints, which reduces air leaks to a minimum. The bends are rounded and there are

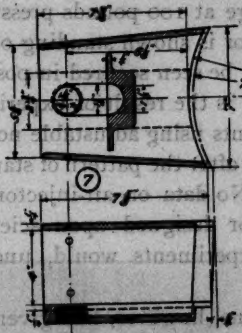


FIG. 2

no air pockets or abrupt changes in the direction of the flow. 9–9, Fig. 3, are the peep holes covered with mica and fitted in a hinged cover. The peep holes are for the purpose of observing the melt, and the covers, when opened, permit the

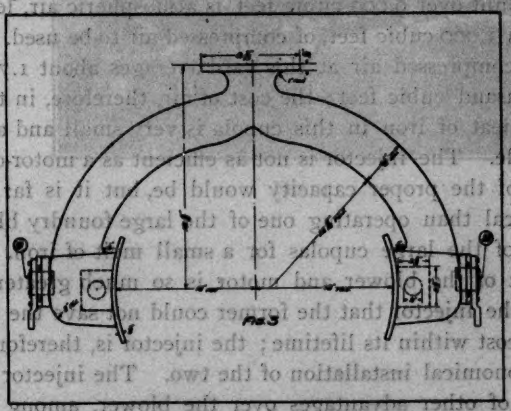


FIG 3

introduction of a bar for clearing away the tuyeres if they become chocked with coke.

12. The method of introducing the blast, so far as known to the writer, is an entirely new departure in cupola practice.

The usual motor-driven fan or impeller-type of blower is absent, and in its place air from the yard compressed-air system is admitted through a three-stage injector, air being admitted to the first stage at 100 pounds pressure through a ¼-inch hole. This injector is shown standing on the foundry floor in Fig. 4, and it can be seen secured in position in Figs. 6, 7 and 8. The injector is the result of experimenting with various nozzle arrangements using adjustable nozzles made of copper tubing and shaped after the pattern of standard impulse steam-turbine nozzles. No data on air-injector design could be obtained. An injector designed upon scientific data or upon more extended experiments would, undoubtedly, be much more efficient.

13. This home-made one, however, has given very fair results, actual measurement showing that it delivers from twelve to fifteen volumes of free air for one volume of compressed air used.

14. In melting 600 pounds of iron (the normal capacity of this furnace) about 10,000 cubic feet of free air is used, and of this amount over 9,000 cubic feet is atmospheric air, leaving less than 1,000 cubic feet, of compressed air to be used. The cost of compressed air at this yard averages about 1.7 cents per thousand cubic feet; the cost of air, therefore, in taking down a heat of iron in this cupola is very small and almost negligible. The injector is not as efficient as a motor-driven blower of the proper capacity would be, but it is far more economical than operating one of the large foundry blowers on one of the large cupolas for a small melt of iron. The first cost of the blower and motor is so much greater than that of the injector that the former could not save the difference in cost within its lifetime; the injector is, therefore, the more economical installation of the two. The injector has a number of other advantages over the blower, among them being the following:

1. It is light and portable and does not interfere with the portable feature of the cupola itself.

2. It is practically unbreakable and requires no repairs.

FIG. 4.

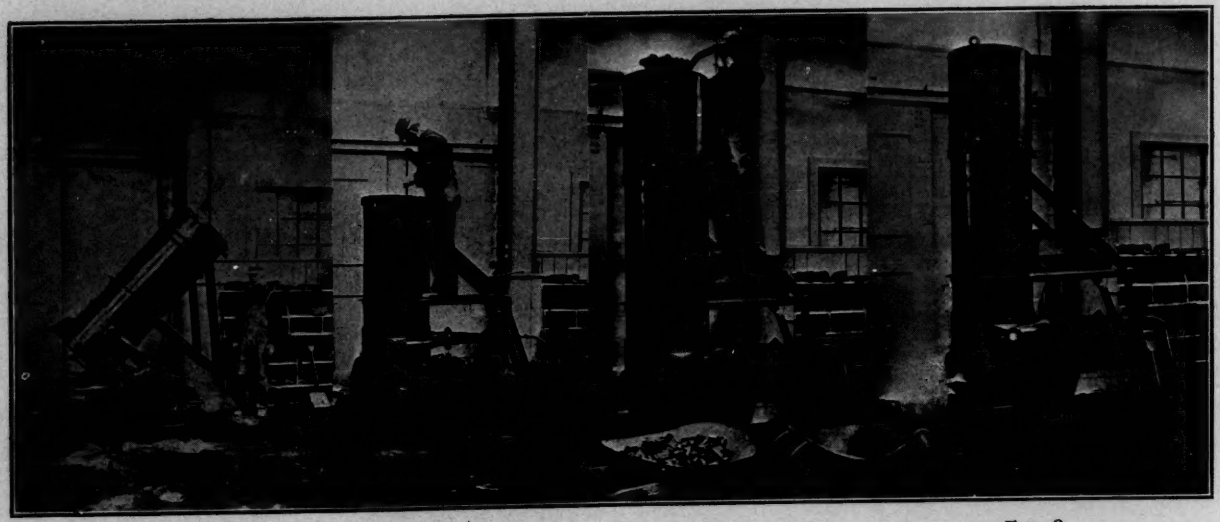


FIG. 5. FIG. 6. FIG. 7. FIG. 8.

3. It has no incidental expenses such as oiling, cleaning and overhauling.

4. Its efficiency remains constant.

15. The cupola lining, which is shown at 10 in Fig. 1, is 4½ inches thick. It is made of arched fire brick set with fire clay. A wood fire is burned in the cupola for six or eight hours to dry out a new lining. A 4½-inch lining should last about 300 heats with care.

16. The charging platform, shown at 11 in Fig. 1 and in Fig. 7, becomes a support for the cupola when lowered to the horizontal position as shown in Fig. 4.

17. There are three eye bolts in the bottom plate which are used for hooking on a three-piece sling when the cupola is to be lifted and moved about. One of these eye bolts is shown at 12 in Fig. 1.

OPERATION.

18. The operation of this cupola does not vary in principle from that of the ordinary type. The lining is patched and made ready for use while the cupola is in the horizontal position, as in Fig. 4; it is then hoisted (see Fig. 5) to the vertical position. Fig. 6 shows the melter ramming in the sand bottom. A wood fire is then started, the coke bed gradually built up and, when burning well up to the height of the tuyeres the "breast" or "front" of fire clay and ground fire brick is built in the mouth of the cupola, leaving a tap hole to be plugged later. When the bed is well lighted up the charging commences, a charge of iron being placed on top of the bed and of about three times the weight of the bed. Coke and iron are then charged alternately in even layers and in the proportion of 8 to 10 pounds of iron to one of coke. Charging is done by hand, as shown in Fig. 7.

19. The blast is then turned on and just as the iron commences to melt the tap hole is plugged. As the fuel and iron settle a few more splits of coke and iron may be charged. The melter watches the progress of the melt through the peep hole, and when the molten iron in the bottom of the cupola

rises nearly to the height of the tuyeres the cupola is tapped, the iron drawn off, and the tap hole plugged again until enough iron is melted for the next tap. The entire charge of iron having been melted and tapped, the bottom is dropped, the cupola is laid horizontally and, when cool, is shipped out, patched up and made ready for another melt.

RESULTS OBTAINED.

20. This cupola has been in use about six months and the results obtained with it have exceeded expectations. It is not only economical in coke consumption for such a small cupola, but is a very rapid melter and produces good, hot, "live" iron. It can be moved in a few minutes to any part of the foundry and, in fact, should there be any necessity, could be moved to any shop or any part of the yard where a hose connection to the compressed-air line could be made. No stack or hood is needed, as the amount of smoke made is very small.

21. The following two tables show typical performances of the cupola and the method of charging. It will be noticed that the first tap, or about 200 pounds of iron, is melted within fifteen minutes after the blast is put on and that the entire charge is melted in about thirty minutes.

Table I.

Charge.	1	2	3	4	Total.
Coke,	70	15	15	15	115
Iron,	250	150	150	150	700

	Hrs.	Min.
Wind on,	2	25
First tap,	2	40
Second tap,	2	48
Third tap,	2	52
Fourth tap,	2	58
Total Time,	0	33

	Pounds.
Weight of castings, gates, etc.,	659
iron recovered,	1
Total iron melted,	660
Melting loss in pounds,	40
Percentage of melting loss,	5.7
Coke charged,	115
recovered,	6
used,	109

Melting ratio: 6.05 pounds of iron per pound of coke.

Table II.

Charge.	1	2	3	Total.
Coke,	80	20	15	115
Iron,	275	175	125	575

	Hrs.	Min.
Wind on,	3	55
First tap,	4	10
Second tap,	4	17
Third tap,	4	25
Total time,	9	30

	Pounds.
Weight of castings, gates, etc.,	537
iron recovered,	17
Total iron melted,	554
Melting loss in pounds,	21
Percentage of melting loss,	3.65
Coke charged,	115
recovered,	16
used,	99

Melting ratio: 5.6 pounds of iron per pound of coke.

22. From 600 to 700 pounds of iron can be melted with 115 pounds of coke in this cupola; to melt this amount in the 24-inch cupola would require 300 pounds of coke.

23. The foreman molder was recently given a pattern for an iron casting with orders to get it out in the least possible

time. While the mold was being made the small cupola was lighted up, and charged and iron was ready very shortly after the mold was finished. The total elapsed time from the instant of giving the order to the foreman to the pouring of the mold was exactly one hour and thirteen minutes. This was without previous preparation and could be duplicated at any time.

24. The small cupola has a number of other advantages in addition to economy of melting small quantities of iron and the rapidity with which it can be prepared, charged and operated. If a large cupola is being operated and regular heat for the day is a soft or medium iron, the small cupola may be used for melting a hard, close iron for such castings as require it, or the reverse of this condition may sometimes hold. A hard iron melted in the small cupola may be mixed with a soft iron from the regular melt, and an iron of any desired intermediate degree of hardness may be obtained.

25. The usual foundry practice is to pour iron castings late in the afternoon, just before quitting time. In busy times the small cupola may be used to take off one or two heats in the morning and permit important work to be delivered four or five hours in advance of the usual time. It may be used for melting small quantities of spiegeleisen, ferro-manganese or ferro-silicon which are to be used in a converter in making steel castings.

26. The method of introducing the blast makes this cupola independent of the blowers; it may therefore, be relied upon for use if the blowers or their motors are broken down.

27. It may be used for brass as well as iron. This fact suggests its suitability for use on ships in place of the oil-burning crucible brass furnaces now used by some ships having small foundries. With a few slight changes in the design this cupola could be made suitable for ship's use. It would require less space than the crucible furnace and would permit ships to make their own iron castings up to 200 or 300 pounds, as well as brass castings.

28. The changes in design for this use would consist of a reduction to 12 inches of the inside diameter, a reduction in the height of the cupola and the thickness of the lining and the elimination of the charging platform and ladder. Either the injector and the ship's air compressor or a small blower could be used, the choice between the two systems depending upon local conditions.

THE UNA-FLOW STEAM ENGINE.

By A. C. Meyers, B. C. S., Efficiency Engineer, Member.

The word "Una-Flow" is a shortening of the term "Uni-Directional Flow," the name being derived from the action of the steam in the cylinder. It simply means that the flow of steam is not changed, as in the cylinder of the ordinary reciprocating engine, but travels only in one direction. This is shown by the arrows in the diagram of the cylinder, Fig. 1.

It will be seen that steam is admitted at each end of the cylinder and exhausted in the middle. The heads, as a rule, are jacketed by the incoming steam, which flows through the heads before passing through the valve ports. The valves are generally very simple, being of the "poppet" type. It is seen from this explanation of the action of the steam that the hot ends of the cylinder T_1 are always hot, and the cooler exhaust belt T_2 always cool. The advantage and economy of this is readily understood; the expansion curve is adiabatic for saturated steam, and the compression curve adiabatic for superheated steam.

As the steam expands after cut-off it increases in wetness; due to the expansion, the wettest steam will follow the piston and the hottest and dry steam will be close to the jacketed heads. As the piston passes the exhaust openings the wet steam will be released, and on the return stroke the hottest steam will be caught and compressed. It is therefore plain that the Una-Flow engine more nearly approaches a perfect heat engine.

In a triple-expansion marine engine (counter-flow) in each cylinder the cooler steam after expansion is to a certain extent carried back over the hotter cylinder surface, thereby cooling

this part of the cylinder. This increases the initial condensation. Even jacketing does not overcome this, for it is shown practically in a multiple-expansion engine that in jacketing the H.P. there is really no advantage, in the I.P. some advantage, and in the L.P. we find the greatest advantage; the greatest advantage being in the L.P. because the difference in temperature between the jacket steam and steam in the cylinder is greatest.

Suppose we superheat in a multiple-expansion engine, while we find there is some economy, as a rule we find the superheat too great for the H.P. and too low for the I.P. and L.P. cylinders.

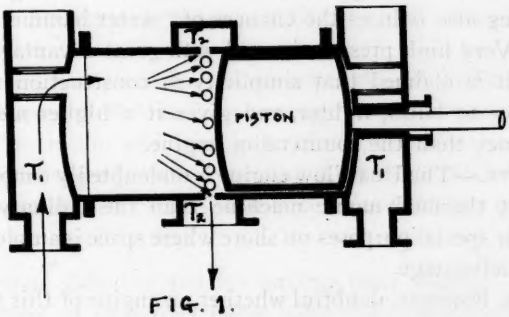


FIG. 1.

Referring to article on "Method of Securing Economy in Steam Consumption," J. A. S. N. E., May, 1914. The foundation of principle of economy is shown by the formula for a simple heat engine $\frac{T_1 - T_2}{T_0}$, and by considering how T_1 may be increased and how T_2 may be decreased. This formula is very simple and fundamental, yet it is often lost sight of in engine design and operation.

It is because the Una-Flow is so suited to the use of superheated steam and high efficiency of the condensing apparatus that such great records of economy in steam consumption have been obtained with this type.

Another great advantage is that the Una-Flow engine has fewer moving parts, thus increasing the mechanical efficiency.

The advantages of the Una-Flow engine for marine service would be as follows:

1. Wet exhaust steam does not come in contact with parts of the cylinder which should always be hottest.

2. Due to the fact that it more nearly obeys the laws of a perfect heat engine its economy is very readily increased by raising T_1 and reducing T_2 in the formula $\frac{T_1 - T_2}{T_0}$.

3. The annular exhaust openings around middle of cylinder permit of much larger exhaust port area, thereby reducing the friction in the passages and tending to bring cylinder pressure down to condenser pressure at end of stroke. Large exhaust opening also reduces the chances of "water hammer."

4. Very high pressure is used with great advantage.

5. It is claimed that simplicity in construction makes it cheaper to build, lighter, and gives it a higher mechanical efficiency than the counter-flow engine.

NOTE.—The Una-Flow engine is undoubtedly a more nearly perfect thermodynamic machine than the ordinary engine, and for special purposes on shore where space is ample it offers great advantage.

It is, however, doubtful whether an engine of this type will make much progress in the marine field. It has possibilities in certain directions such as engines for steam launches and small yachts, and the driving engines of blowers, circulating pumps and small dynamo engines where turbines are not used. It would appear that its proper field is on vessels where superheated steam is used.

It is difficult to see how this type of engine can be made either lighter or less complicated than the alternate-flow reciprocating engine since it is a single-acting engine and requires a long cylinder.—H. C. D.

STRESSES IN STEAM-BALANCED VALVE GEARS.

By Ernest N. Janson, Member.

REFERENCES:

1. The Balancing of Valve Gears, by Luther D. Lovekin, published in the "Transactions of the Society of Naval Architects and Marine Engineers," 1902.
2. Performance of the Assistant Cylinders of the *Washington*, by W. W. Smith, published in Journal of the American Society of Naval Engineers, Volume XVIII, 1906.
3. Balance Pistons and Joy's Assistant Cylinder, published in "Manual of Marine Engineering," by A. E. Seaton.
4. For description and principles of the Lovekin Assistant Cylinder, see Journal of the American Society of Naval Engineers, Volumes XVI and XVII, 1904 and 1905.

Numerous valuable articles having been written on the main subject of balancing valve gears the following is contributed chiefly for the purpose of ascertaining forces, incidental upon balancing, and to determine stresses and dimensions. Circumstances governing the adoption of means and methods of balancing are alluded to by way of actual installations given in table below. The comments generally seem warranted by the continued extensive use of reciprocating engines.

MEANS OF BALANCING.

The main cylinder steam-distributing valves in engines for marine use are invariably composed of slide valves and are usually operated by the Stephenson link and eccentric motion.

In the United States Navy the valves are commonly of the piston type to the exclusion of the flat valve, which, however, is yet in favor on the low-pressure cylinders in engines of the merchant marine service.

The principal stresses created in valve gears as a result of reciprocating motion are caused by inertia, weight and friction. With piston valves only inertia and weight need be considered, while with flat valves, especially those not fitted with relief frames, stresses due to friction must, of course, also be taken into account. In all cases we may consider the gears substantially rigid, and in engines with long stroke and short valve travel the obliquity of eccentric rods may be neglected. But in engines of considerable power and of comparatively short stroke, but with long valve travel, as is usual in naval engines, the effect of obliquity is noticeable and influential in creating a difference of some magnitude in the inertia forces in the up- and down-strokes. Means at hand to relieve the stresses resulting from the causes above enumerated are:

1. To balance for weight alone, by application of ordinary balance cylinders.

2. To balance for both weight and inertia, by application of automatic pressure cylinders of, for instance, the Lovekin type.

3. To balance for friction, which consists in the introduction of some type of relief frame fitted on the back of flat valves, thereby counteracting the steam pressure on the valve's surface.

APPLICATION OF BALANCE.

Judging from facts as they exist in actual practice it is difficult to establish a line of demarcation for the usage or non-usage of balance pistons. Considering stresses and pressures created by the forces acting on the valve gears in comparison with those existing in piston and connecting rods, or in main and crank-pin bearings, the stresses and pressures of the former are only certain fractions of the latter, due mainly to an equilibrium of static steam forces on the valve heads. In this connection consideration should be given to the fact that the valves are driven by the eccentrics while the pistons drive the cranks. Hence excellent results have been obtained with heavy valve gears without provision even for the balance of

weights. In small engines where the reciprocating parts of the valve gear are only of very moderate weight—say 1,000 pounds—and where the product of their mass and acceleration is quite small—say within 1,500 pounds—it seems unnecessary to introduce balance pistons, as the parts, when made according to good standard practice, are usually strong enough to withstand the rather insignificant stresses due to weight, friction and inertia.

In large, heavy and fast-moving engines, such as are used especially for the naval service, balance pistons are, however, of great value and are usually fitted. On the other hand, this is done only occasionally in engines of the merchant service. The reason may be found due to the fact that limitations of dimensions of such parts as the eccentrics are more quickly reached in naval engines than in merchant engines, the space and weight allowances of the latter being usually much more liberal, and the pressures per square inch of operating surfaces, therefore, much reduced.

In the table appended below are given data of a few representative reciprocating engines. The low-pressure cylinder valve gears are chosen as representing maximum strains for all of the ships cited except for *Supply Ship No. 1*, in which the high-pressure cylinder valve gear is given, to show the moderate stress valve gears of this type are subjected to, even when fitted without balance pistons of any kind.

The pressures coming on link pins, link-block gibs and eccentric pins are obtained in the same way as for the eccentrics. These pressures may be limited to come within the following figures for weight-balanced piston valves:

Eccentrics, pounds per square inch projected surface, .	75
Link pins, pounds per square inch projected surface, .	500
Link-block gibs, pounds per square inch of surface, . .	225
Eccentric pins, pounds per sq. inch of projected surface,	450

By comparison with pressures and surface speeds existing in main and crank-pin journals, gudgeons or slippers we find the pressures on corresponding parts in valve gears more favorable.

TABLE I.

Year.	Name of ship.	I.H.P. each engine.	R.P.M.	Stroke of valve.	Gravity effect.	Inertia.	Effective width and diam. of eccentric, ins.	Press. per sq. in. of ecc. surf.	Balancing and type of valve.
				ins.			*Ins.*	*lbs.*	
1902	S. S. *Lorraine*.....	2 engs.	92	...	...	...	5.75	...	Joy's asst. cyl. on *all* valves.
	S. S. *Savoie*.....	11,500					...	...	Pist. valves on H.P. and. I.P. Flat valves on L.P.
1903	S. S. *Kaiser Wilhelm II*...	4 engs. 12,000	80	13	15,000	19,000	7.00 52.00	94	No. bal. cyl. on any of valves. Pist. valves on H.P. and I.P. Flat valves on L.P.
1905	U. S. S. *Louisiana*..	2 engs.	127.6	11	2,625	6,492	4.0 31.0	60	Ordinary bal. pist. on *all* valves. Piston valves on all cylinders.
1911	*S. S. *Olympic*.....	2 engs. 15,000	75	16	22,000	25,000	9.5 52.0	61	Ordinary bal. pist. on L.P. *only*. Pist. valves on H.P. and I.P. Flat valves on L.P.
1914	*S. S. *Britannic*.....	2 engs. 16,000	77	16	20,000	28,000	9.5 52.0	62	Ordinary bal. pist. on L.P. *only*. Piston valves on all cylinders.
1914	U. S. S. *Texas*.....	2 engs. 14,200	124.5	12	7,380	22,686	5.5 35.5	31	Lovekin asst. cyl. on *all* valves. Piston valves on all cylinders.
Building.	†U. S. *Supply Ship, No. 1.*	2 engs. 2,000	90	7	†1,100	†860	2.75 27.0	‡25	Lovekin asst. cyl. on *all* valves. Piston valves on all cylinders.

*Combination machinery, 2 reciprocating engines, 1 L.P. turbine.

†Gravity effect and inertia given for H.P. cylinder valve.

‡Pressure on eccentric given is that which would prevail were there *no* balance piston of any kind fitted.

Where flat valves are used relief frames are fitted. Pressures per square inch of projected eccentric surface given above are those which are due to maximum loads. These loads occur at the end of stroke. Fig. 1 gives pressures per square inch of projected eccentric surface for maximum and mean loads.

When made of at least 60,000 pounds steel a tensile stress per square inch of effective area of pin-bearing bolts up to 3,000 pounds, and on strap bolt up to 5,000 pounds, may be used. Said stresses are, however, invariably only one-half, in order to secure a rugged and substantial construction.

SYNOPSIS.

Force due to gravity or weight of valves, valve stems and balance pistons, link block, one eccentric rod, one eccentric strap, together with one-half of links and suspension rods, or total gravity effect of any one valve gear, ... W

Force due to steam pressure on top of each balance piston, at top and bottom stroke respectively, . W_{1t} and W_{1b}

Force due to steam pressure on bottom of each balance piston at top and bottom stroke, respectively, . W_{2t} and W_{2b}
Force due to unbalanced pressure at end of down-stroke, ... W_d
Force due to unbalanced pressure at end of up-stroke, W_u
Force due to unbalanced receiver pressure on lower balance piston (Lovekin type), ... W_c
Force on nut at balance piston due to difference in pressure at end of down-stroke, bottom and top, . W_n
Length of eccentric rod between centers, feet, . . L
Eccentricity, feet, ... r
Ratio length of rod to that of eccentricity $= \frac{L}{r}$, . . n
Area of section of eccentric rod at middle, square inch, A
Area of valve stem at nut on balance piston, sq. in., . A_1
Area of eccentric strap bolts at nut, square inch, . A_2
Revolutions of shaft per minute, ... R
Angular velocity at unit radius in radians per second $= \pi R \div 30$, ... ω
Mass corresponding to W, or $\frac{W}{g}$, ... m
Acceleration of reciprocating parts in feet per second per second, ... F
Acceleration of reciprocating parts at end in up-and down-stroke, respectively, ... F_u, F_d
Stress per square inch of section of material, . . f_t
Angle turned by the eccentric arm measured from the top dead center of valve gear, ... θ
Acceleration due to gravity, ... $g = 32.2$
Pressure in pounds per square inch of surface, . . p
Total effective surface of pins, gibs or eccentrics, square inch, ... S
Steam pressure above balance piston, lbs. per sq. in., . p_1
Steam pressure below balance piston, lbs. per sq. in., . p_2
Number of balance pistons, ... N
Inertia of moving parts of valve gear coming on each balance-piston end of up-stroke, ... I_u
Inertia of moving parts of valve gear coming on each balance-piston end of down-stroke, . . . I_d

INERTIA FORCES.

Derivation of formulas for acceleration may be found in nearly any text book on applied and theoretical mechanics, and is comprehensively treated in the article by Mr. Lovekin previously referred to.

It is of interest to point out the influence of obliquity of eccentric- or connecting-rod on the velocity of the reciprocating parts at different points of the stroke and, in consequence

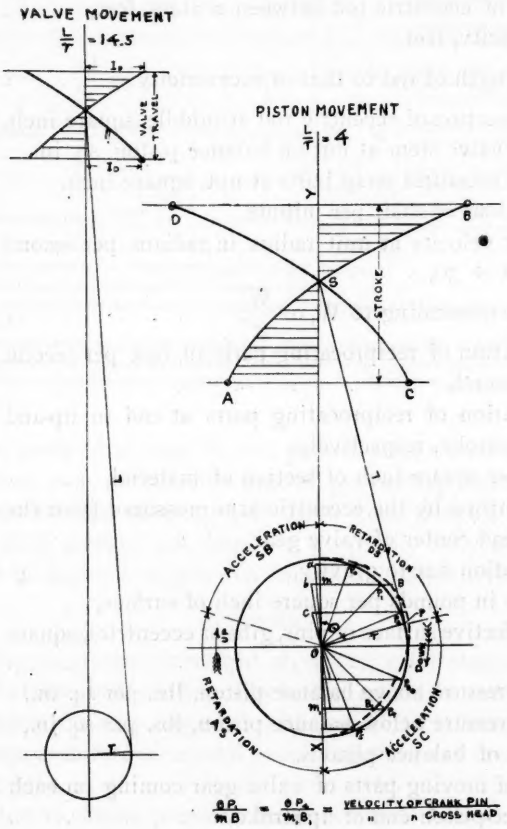


FIG. 1.

thereof, the acceleration to which inertia forces bear an important relation. In the diagram of cross-head and crank movement given in Fig. 1, it can be readily proven that, where the velocity of the crank is represented by the length of crank-arm, the length of the ordinates, drawn from crank positions P_0, P_1, P_2, etc., to center line X—Y, represents the velocity of the crank and relatively to it of the reciprocating parts during the stroke.*

With an infinitely long connecting rod (which, of course, is impossible practically, but has an equivalent in certain mechanical devices) the center line of the connecting rod will be parallel to the axis X—Y and the dotted curve becomes a semi-circle which is the crank-path itself. Where $L \div r$ is very large, say above 25, the velocity of the crank-pin becomes approximately uniform and the motion of the reciprocating parts approaches simple harmonic motion. The acceleration of the parts constituting the valve gear may then be obtained, without appreciable error, from

$$F = \omega^2 r \operatorname{Cos} \theta \quad . \quad . \quad . \quad . \quad . \quad (1)$$

At the beginning and end of stroke, counting θ from the upper dead center, we get respectively for $\theta = 0°$ and $\theta = 180°$:

$$F_u = \omega^2 r \text{ and } F_d = -\omega^2 r.$$

The inertia corresponding to those positions will be:

$$I_u = m\omega^2 r \text{ and } I_d = -m\omega^2 r.$$

A considerable difference, however, is shown in the acceleration at end of up- and down-strokes for any substantial diminution in the ratio $L \div r$. The value of the acceleration for any crank position and a value of $L \div r = n$, is then found from:

* For the design of the dotted curve shown proceed in the following manner: Erect from crank positions P_0, P_1, P_2, etc., perpendiculars against X — Y. Draw through O lines parallel to connecting rod for different crank positions, and offset from X — Y respective lengths of ordinates determined by the intersection of line aO, bO, cO, etc., and points P_0, P_1, P_2, etc.

$$F = \omega^2 r \left\{ \cos\theta + \frac{\cos 2\theta}{n} \right\}, \quad . \quad . \quad . \quad . \quad (2)$$

If, as before, counting θ from upper dead center, we get for: $\theta = 0^\circ$, corresponding to beginning of down-stroke and end of up-stroke,

$$F_u = + \omega^2 r \left\{ 1 + \frac{r}{L} \right\}, \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and for

$\theta = 180^\circ$, corresponding to beginning of up-stroke and end of down-stroke,

$$F_d = - \omega^2 r \left\{ 1 - \frac{r}{L} \right\}, \quad . \quad . \quad . \quad . \quad . \quad (4)$$

direction being indicated by + or —.

The inertia forces corresponding to F_u and F_d will be

$$I_u = F_u \times m \text{ and } I_d = - F_d \times m.$$

Referring again to Fig. 1, it may be pointed out that when n is large, say above 14, curves A B and C D become quite flat and, therefore, said curves may be drawn with a close degree of approximation as soon as point S has been established, points A, B, C and D being established from formulas 3 and 4. The point S is the center of crosshead when crank and connecting-rod form an angle of 90 degrees. Its distance from mid-position varies with $L \div r$, but is easiest found by transposing upon Fig. 1 a triangle, drawn to same scale, where SP and OP are at 90 degrees.

Where $L \div r$ is small, say below 6, the curves in question have a pronounced curvature and the contour should be established by taking different values of θ and F found from formula (2).

Ordinates drawn from curves towards axis X — Y will give magnitude of acceleration for corresponding positions of stroke. At point S, the velocity is a maximum, and acceleration a minimum, and any forces due thereto are neutralized and *nil.*

With ordinary balance pistons the prevailing pressures

above and below the pistons are those of the main exhaust and receiver, dependent in each case upon the connections. But in the automatic pressure-balance cylinder (Lovekin type) the pressures above and below the pistons are those obtained, approximately, by compression or expansion of the steam, above or below the piston according to Mariotte's law. By this law the volume of a given quantity of gas varies inversely as the pressure, provided the temperature be kept constant, or $p_1 v_1 = p_2 v_2 =$ constant. In order to construct the pressure

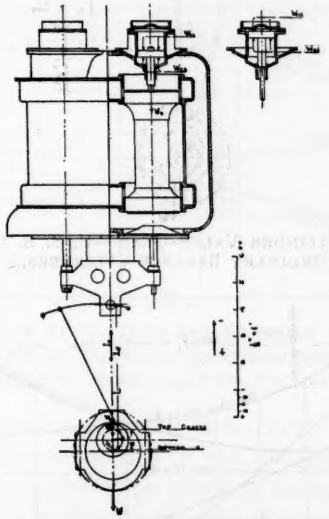


FIG. 2.—L.P. CYLINDER VALVE-GEAR.—U. S. S. "TEXAS." LOVEKIN ASSISTANT CYLINDERS.

curves, from which to ascertain the pressures at any part of the stroke, the cylinder clearance, point of admission and volumes must be carefully established and recorded. Thereafter the gravity effect, or determination of W, as outlined in synopsis, must be established, the inertia in up- and down-stroke calculated and the whole laid down as a diagram upon a fixed base line, using certain chosen scales for stroke, weight and pressures. All of the foregoing is shown in Fig. 4 for

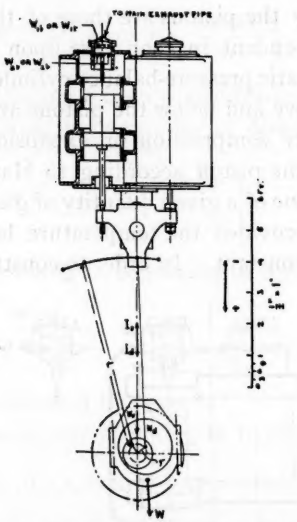
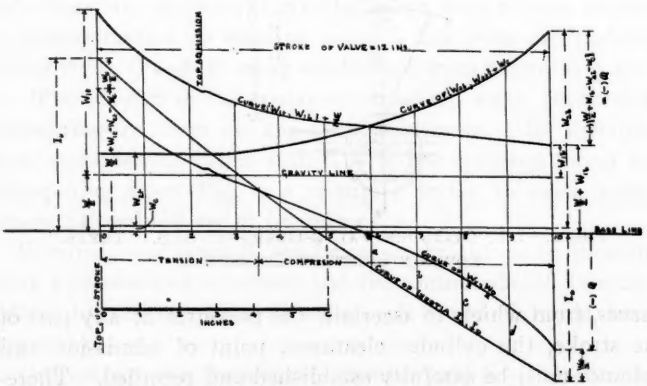


FIG. 3.—L.P. CYLINDER VALVE-GEAR.—U. S. S. "LOUISIANA." ORDINARY BALANCE CYLINDERS.



W_c = Constant for receiver pressure, diameter of valve sleeve and stem used.

Ordinates $\frac{W_u}{2}$, a, b, c, etc., half total unbalanced pressure.

FIG. 4.—INERTIA—PRESSURE—WEIGHT DIAGRAM L. P. CYLINDERS, U. S. S. "TEXAS," LOVEKIN ASSISTANT CYLINDERS.

Scales: { Ordinates, ½-inch = 1,000 pounds. Abscissae, ½-inch = 1 inch

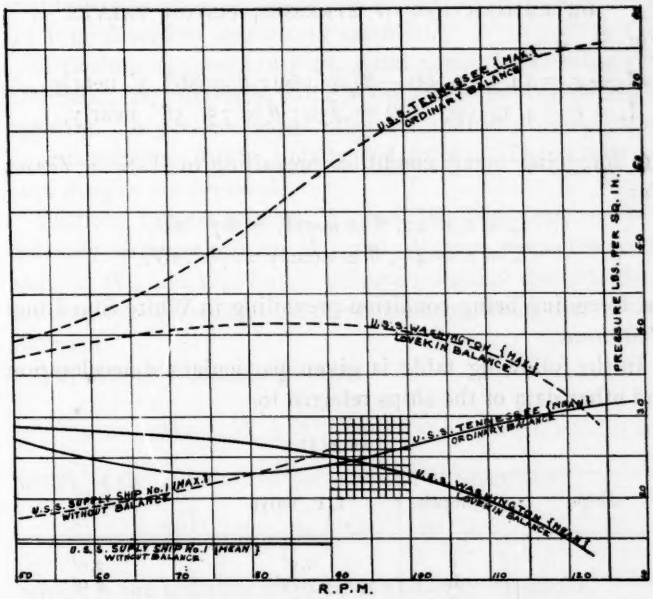


FIG. 5.—CURVES OF REVOLUTIONS AND PRESSURE IN POUNDS PER SQUARE INCH OF PROJECTED ECCENTRIC SURFACE FOR MAXIMUM AND MEAN LOADS ON VALVE-GEARS.

the L.P. cylinder valve gear of U. S. S. *Texas*. For a detailed and comprehensive discussion of the problem the reader is referred to Mr. Lovekin's paper given in the beginning of this article. In Fig. 5 is shown a diagram of pressures per square inch of projected eccentric surface of three vessels, one of which, the *Tennessee*, has ordinary balance cylinders, the second, the *Washington*, is fitted with Lovekin cylinders, and the third, the U. S. *Supply Ship No. 1*, now building, although fitted with Lovekin cylinders, is shown as if *no* provision of balance were provided, the valve gear being for the H.P. cylinder, and the weight, therefore, comparatively small. Special attention is drawn to the curves representing mean pressures which represent the mean of maximum and minimum pressures during the stroke running at the different powers and revolutions.

DETERMINATION OF STRESSES, PISTON VALVES.

For

$$L \div r = 14.5, \text{ tg. } (90 - \theta) = .069; \quad \theta = 86^\circ\ 3', \text{ nearly,}$$
$$L \div r = 4, \text{ tg. } (90 - \theta) = .250; \quad \theta = 75^\circ\ 58', \text{ nearly,}$$

the foregoing being condition prevailing in U. S. S. *Texas*. For

$$L \div r = 22, \ \theta \text{ is nearly} = 87^\circ\ 24',$$
$$L \div r = 4.5, \ \theta \text{ is nearly} = 77^\circ\ 28',$$

the foregoing being condition prevailing in White Star Liner *Britannic*.

In the following table is given particulars of acceleration and other data of the ships referred to.

TABLE II.

Ships.	Synopsis.	L.P. Valve.	Piston.
U. S. S. *Texas*...	r	0.5′	2.0′
	L	7.25′	8.0′
	n	14.5	4.0
	R	124.5	124.5
	$\omega^2 r$	$170 \times .5 = 85$	$170 \times 2 = 240$
	F_u	$85 \times 1.068 = 90.8$	$240 \times 1.25 = 300$
	F_d	$85 \times .93 = 79.0$	$240 \times .75 = 180$
White Star Liner *Britannic*.....	r	0.66′	3.125′
	L	14.5′	14.06′
	n	22.0	4.5
	R	77.0	77.0
	$\omega^2 r$	$65 \times .66 = 36.3$	$65 \times 3.125 = 203$
	F_u	$36.3 \times 1.045 = 37.94$	$203 \times 1.222 = 248$
	F_d	$36.3 \times 0.955 = 34.67$	$203 \times 0.788 = 159$

The examples cited in Table I and II display clearly the momentous effect in the creation of inertia by an increase in the speed of revolutions of reciprocating engines. The inertia increases as the square of the revolutions, but only with the first power of the weight; hence arises the presence of very considerable forces in swift, high-powered marine engines, which forces must either be counterbalanced or taken care of by added dimensions with higher surface pressures. To

counterbalance the forces by steam balancing in engines of the type described seems very essential.

With signs as chosen in Figs. 2 and 3, in order to bring gear in tension, the numerical value of both W_u and W_d should be negative. A positive value of either indicates compression in parts of gear, due to unbalanced forces. The reverse occurs if signs are reversed.

Without balance pistons W_{1t} and W_{2t} disappear, and with ordinary balance pistons W_{1t} and W_{2t} are respectively the same as W_{1b} and W_{2b}, but in balance pistons of the automatic-pressure type (Lovekin) the corresponding values may be very different.

For ordinary balance pistons:

$$W_u = W + N\left\{ W_{1t} - W_{2t} - I_u \right\}, \quad . \quad . \quad . \quad (5)$$

which is the unbalanced force at end of up-stroke.

$$W_d = W + N\left\{ W_{1t} - W_{2t} + I_d \right\}, \quad . \quad . \quad . \quad (6)$$

which is the unbalanced force at end of down-stroke.

For automatic pressure-balance pistons (Lovekin):

$$W_u = W + N\left\{ W_{1t} - I_u - (W_{2t} + W_c) \right\}, \quad . \quad (7)$$

which is the unbalanced force at end of up-stroke.

$$W_d = W + N\left\{ W_{1b} + I_d - (W_{2b} + W_c) \right\}, \quad . \quad (8)$$

which is the unbalanced force at end of down-stroke.

$$W_n = -(W_{2b} - W_{1b}), \quad . \quad . \quad . \quad . \quad . \quad (9)$$

which is the unbalanced on the nut of each balance piston.

It is essential, or at least very desirable, to keep stresses and pressures quite low in parts pertaining to valve gears. The maximum force during the stroke as well as that developed for maximum power should always be used, but in no case should dimensions be wholly settled from calculated values, owing to the numerous uncertain items, such as work-

manship, material, vibration, careless operation, etc., entering in giving working results.

The formulas appended below may be used for checking.

$$\frac{W_u \text{ or } W_d}{p} = S, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$\frac{W_u \text{ or } W_d}{f_t} = A_2, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$\frac{W_n}{f_t} = A_1, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

$$\frac{W_d\left\{1 + .0008\left(\frac{12L}{d}\right)^2\right\}}{f_t} = A, \quad . \quad . \quad . \quad (13)$$

d (diameter of rod at middle) may require modification to agree with value obtained for A.

Two actual examples are given in the following, illustrating condition when ordinary and automatic balance pistons are used.

U. S. S. *Louisiana.*—L.P. cylinder gear having ordinary balance cylinders, balancing for weight only.

Number of valves and balance pistons, . . .	2
Diameter of each balance piston, inches, . . .	$8\frac{1}{2}$
Stroke of each balance piston, inches, . . .	11.0
Area of each balance piston, top, square inches, .	56.7
bottom, square inches, .	55.0
Receiver pressure, pounds per square inch, absolute,	42.8
Pressure on top of balance piston, pounds per square inch, absolute, ...	2

$2W_{1t} = 2W_{1b} = 2 \times 56.7 \times 2 = 226.$

$2W_{2t} = 2W_{2b} = 42.8 \times 55 \times 2 = 4{,}700.$

$L = 7.83$ feet.

$r = .45$ feet.

$R = 130$ (maximum run).

$$\omega = \frac{\pi \times 130}{30} = 13.6; \quad \omega^2 = 185.$$

$W = 2{,}624$ pounds.
$m = W \div g = 81.49$.
$F_u = 185 \times .45 \times 1.052 = 87.3$.
$F_d = 185 \times .45 \times 0.918 = 76.9$.
$2I_u = 81.49 \times 87.3 = 7{,}112$.
$2I_d = 81.49 \times 76.9 = 6{,}265$.
$W_u = 2{,}624 + 226 - 4{,}700 - 7{,}112$
$= -8{,}962$ pounds, gear in tension.
$W_d = 2{,}624 + 226 - 4{,}700 + 6{,}265$
$= +4{,}415$ pounds, gear in compression.
$S = 124$ square inches, projected eccentric surface.
$\frac{W_u}{S} = \frac{8{,}962}{124} = 72.2$ pounds per square inch of projected surface.

NOTE.—By increasing diameter of each balance piston from 8½ inches to 16½ inches, the gear would be in tension in both up- and down-stroke, the disadvantage being the very high pressure in up-stroke.

U. S. S. *Texas*.—L.P. cylinder gear having automatic pressure balance cylinders of Lovekin type, balancing for both weight and inertia.

Number of valves and balance pistons,	2
Diameter of each balance piston, inches,	16
Stroke of each balance piston, inches,	12
Volumetric clearance, top, cubic inches,	603
Volumetric clearance, bottom, cubic inches,	928
Area balance piston, top, square inches,	201
Area balance piston, bottom, square inches,	183
Receiver pressure, pounds per square inch, abs.	26.5

Steam admission above balance piston closes 3.125 ins. from top.
Steam admission below balance piston closes 3.5 ins. from top.

Steam volume at top cushion, cubic ins.,	1,230.
Steam volume at bottom cushion, cubic ins.,	2,490.

	lbs. per sq. in.	lbs.
At beginning of down-stroke	$p_1 = 54.1$;	$W_{1t} = 10{,}870$
.1 of down-stroke	$= 38.7$;	$= 7{,}780$
.26 of down-stroke	$= 26.5$;	$= 5{,}525$
.5 of down-stroke	$= 17.5$;	$= 3{,}520$
.75 of down-stroke	$= 13.9$;	$= 2{,}790$
end of down-stroke	$= 10.8$;	$W_{1b} = 2{,}170$

	lbs. per sq. in.	lbs.
At beginning of down-stroke	$p_2 = 26.5$;	$W_{2t} + W_c = 5{,}240$
.1 of down-stroke	$= 26.5$;	$= 5{,}240$
.291 of down-stroke	$= 26.5$;	$= 5{,}240$
.5 of down-stroke	$= 32.5$;	$= 6{,}297$
.75 of down-stroke	$= 44.6$;	$= 8{,}512$
end of down-stroke	$= 71.4$;	$W_{2b} + W_c = 13{,}416$

$L = 7.25$ feet.

$r = 0.5$ feet.

R = 130 (maximum run).

$$\omega = \frac{\pi \times 130}{30} = 13.6; \quad \omega^2 = 185.$$

W = 7,380 pounds.

$m = W \div g. = 229.2$.

$F_u = 185 \times .5 \times 1.07 = 98.97$.

$F_d = 185 \times .5 \times 0.93 = 83.165$.

$2I_u = 229.2 \times 98.97 = 22{,}686$ pounds, end of up-stroke,

$2I_d = 229.2 \times 84.165 = 19{,}290$ pounds, end of down-stroke.

$W_u = 7{,}380 + 2\{10{,}870 - 11{,}343 - 5{,}240\} = -4{,}046$, gear in tension.

$W_d = 7{,}380 + 2\{2{,}170 + 9{,}645 - 13{,}416\} = +4{,}178$, gear in compression.

$W_n = -(13{,}066 - 2{,}170) = -10{,}896$, tension on valve stem at nut of piston.

S = 124.5 square inches, projected eccentric surface.

$$\frac{W_d}{s} = \frac{4{,}178}{124.5} = 33.5 \text{ pounds.}$$

DETERMINATION OF STRESSES, FLAT VALVES.

The pressure on a slide valve of the flat type is caused by the difference in the outside and inside pressure on the valve,

the pressure inside being dependent on the position of the valve with respect to the ports in the cylinder. The outside pressure is due to the steam pressure in the valve chest, and the friction of the valve to conditions of lubrication between the sliding surfaces. When relief frames are fitted the pressure on the valve becomes almost wholly eliminated and its movement will be practically the same as that of piston valves.

If an extreme value of .2 is given as the coefficient of friction and the valve be assumed one not fitted with relief frames, then a force equal to the frictional resistance will be added to, for the first half and deducted from for the second half of each stroke, the forces produced by weight and inertia of the gear. As the greatest pressure difference outside and inside of the valve occurs at the extreme end of each stroke, it is evident a very considerable force may have to be overcome at the beginning of each stroke, especially that of the up-stroke in a vertical engine.

EFFECT OF BALANCE.

The mean stress and surface pressure on any part of the valve gear is a result of the mean value of the unbalanced forces during up- and down- strokes for a number of revolutions. The forces created by inertia at any stage of the gear are calculated as due to the entire weight of the gear.

Wear may reasonably be assumed to be caused by the average pressure during the up- and down- stroke. The system of balance which provides for the greatest reduction of unbalanced forces during any range of operations should be conducive of giving greatest efficiency. The mean value of the unbalanced forces W_u and W_d acting on the gear will in each case establish the mean load from which wear may be ascertained. Stress in the different parts must always be figured from maximum unbalanced load.

Steadiness in operation of valve gears is materially aided by eliminating as much as possible the forces which bring the gear alternately in tension and compression, the latter being often the cause of vibration.

THE ENGINEER DEPARTMENT OF NAVAL VESSELS.

NOTES AND SUGGESTIONS CONCERNING ORGANIZATION, ADMINISTRATION AND DUTIES OF OFFICERS.

*COMPILED BY H. C. DINGER, LIEUTENANT COMMANDER, U. S. N., MEMBER.

CONTENTS.

		Page.
I.	The Senior Assistant	1183
II.	Duties of other Engineer Officers	1184
III.	Junior Assistants	1188
IV.	Chief Petty Officers	1195
V.	Stations and Sub-stations	1196
VI.	Officers in Charge of Stations	1204
VII.	Watch and Day's Duty	1212
VIII.	Officers in Charge of Sections	1231
IX.	Sources of Knowledge	1234
X.	The Engineer's Office	1236
XI.	Engineer's Yeoman	1249
XII.	The Log	1250
XIII.	Engineer's Journal.—Remark Book	1252
XIV.	Job-Order Index.—Daily Work Lists	1257
XV.	Stores and Storekeeping	1262
XVI.	Receiving New Men	1265
XVII.	Liberty and Special Requests	1266
XVIII.	Reports of Delinquency	1268
XIX.	Duty Section	1269
XX.	Special Instructions for Petty Officers	1270
XXI.	Routine Tests and Inspections	1271
XXII.	General Operation of Machinery	1271
XXIII.	Care and Operation	1284
XXIV.	Conduct of Business in Engineer Department	1290
XXV.	General Information for Engineer's Force	1292
XXVI.	General Information for Officer of Deck and Ship's Officers	1296

FOREWORD.

The following notes have been prepared with a view of having available for reference by officers newly detailed to engineering duty afloat a general resumé of the manner in

*The compiler of these notes has been specially assisted by Lieutenant Commander A. W. JOHNSON, U. S. N., who prepared a large portion of the matter. Special assistance in the matter of criticism and suggestions have been given by Lieutenant Commander FRANK MCCOMMON; Lieutenant J. O. RICHARDSON; Lieutenant W. T. CONN, JR.; Lieutenant M. S. DAVIS; Lieutenant R. C. DAVIS; Lieutenant A. T. CHURCH and Lieutenant R. L. IRVINE.

which the Engineer Department is organized and administered, and to aid if possible in bringing about more uniformity in practice by presenting to the engineering personnel what is believed to be the most generally satisfactory practice.

The notes have been prepared from all available information, especially from actual orders successfully used on naval vessels, and in compiling them the opinions of many officers of large engineering experience have been considered. The notes are neither complete nor original, and are intended to indicate what actually is done. Individual matters on individual vessels are no doubt in many cases better and more fully treated on that individual vessel; but it is believed that in these notes some suggestion for improvement over methods in force on any one vessel may be found. Representing, as they do, a concensus of opinion of best practice, it is hoped that they will be of considerable value to officers performing engineering duty.

The information herein given applies more particularly to conditions on capital vessels, but the information is of value to engineer officers on other vessels as well.

On small vessels the subdivision of stations can be made very much along the same lines, and chief petty officers are assigned in charge, instead of commissioned and warrant officers.

I.—SENIOR ASSISTANT.

1. The Senior Assistant is usually assigned to the duty of supervising office details not specially performed by the Engineer Officer. The division of duties is arranged in a somewhat different manner on different vessels. The following is a list of matters usually assigned to the Senior Assistant:

(*a*) Keeping engineering competition data and forms.

(*b*) Preparation of engineering records, data, etc.

(*c*) Operating job-order system.

(*d*) Supervision over supplies and equipage, preparation of memo. for requisitions.

(*e*) Instruction of men. Senior member of Examining Board for men.

(*f*) Keeping station bills corrected.

(*g*) Keeping repair book and repair file.

(*h*) General oversight over all work with a view of suggesting methods of improvement, etc.

(*i*) Supervision of bunker inspection, oil account and other similar records.

(*j*) Preparation of routine and special engineering reports.

(*k*) Engineer member of Hull Board.

The senior assistant is also in some cases assigned as the commissioned officer on one of the repair stations, and usually takes the forenoon watch at sea. He may or may not take day's duty, depending on the number of engineer watch officers available.

He is not assigned to a section, but as the special aid to the engineer officer has general supervision over all the personnel of the engineer department.

The senior assistant should keep in special touch with all matters going on and thoroughly understand the policies that the engineer officer desires to carry out in order that he may carry out all matters as contemplated in the absence of the engineer officer. The senior assistant is usually not detailed for any duty outside of the engineer department, except boards, courts, etc.

II.—DUTIES OF OTHER ENGINEER OFFICERS.

2. Commissioned line officers, chief machinists and machinists are assigned to the engineer department. The qualified commissioned officers are designated as Assistant Engineer Officers. Their work consists of doing duties as engineer officers of the watch at sea, and engineer officer of the day in port; as officers in charge of stations in the engineer's department, and as officers in charge of sections of the engineer division.

Each officer should be given a copy of the REGULATIONS

AND INSTRUCTIONS OF THE ENGINEER DEPARTMENT of the vessel for his guidance. These should be read over carefully, and retained by the officer until he is detached, when he returns them to the engineer officer, with all changes and additions correctly entered to date.

3. Officers, after reporting, should make every effort to familiarize themselves with the organization of the department, methods of carrying on the work, with the general lay-out of the machinery and its construction, especially that of the station to which they are assigned. They should as soon as possible acquaint themselves with the names and capabilities of the leading petty officers and with the men of their station. It is particularly important that all officers familiarize themselves with the lead of the piping and the location of all important valves of the steam, feed, drain and fuel-oil lines, without delay. They should also study the Department Instructions and Regulations relating to the care, preservation and operation of machinery on board ship, which are contained in the Naval Regulations and Naval Instructions. They should especially inform themselves concerning the methods in force on the vessel governing the relations of the officers of the engineer department with the officer of the deck, executive officer, first lieutenant, etc.

ASSIGNMENT OF OFFICERS TO STATIONS.

4. The most usual practice, and one that should be made uniform, is to divide the engineer department into three repair stations—*Engine Rooms, Boiler Rooms, Auxiliaries.* This division can be made to apply to nearly all vessels in the Navy.

Either a commissioned assistant or one of the warrant officers is assigned in charge of each of the above stations, and the assignment should be made, not on the basis of rank, but rather on that of the special qualifications of the officer for the station in question.

When a sufficient number are available, the assistant engineer officers (qualified commissioned officers), are in most cases assigned to stations in conjunction with the warrant

officers, there being both a warrant officer and a commissioned officer on the station; but in other cases the officers are assigned independently, and more repair stations than those above mentioned are made.

5. The commissioned officers other than senior assistant are not assigned in any definite number, and usually have duties with the battery which take them out of the engineer department for considerable portions of the time during working hours. For this reason, under conditions prevailing it is often considered that the best total result will be obtained if the commissioned officer is assigned to a station in connection with the warrant officer, and rules as to their respective responsibility made.

6. The following are rules which have been found to be entirely successful and which are believed to be based on proper principles and which might be adopted on all large vessels:

"A commissioned and a warrant officer is usually assigned to each repair station.

" Each have certain responsibilities.

" Commissioned Officer on the Station.

" The assistant engineer officer is in the position of an inspector, critic and consulting authority on the station.

" He is also a supervisor over the work done and he is responsible for pointing out to the warrant officer and bringing to the attention of the senior engineer, any defects, incorrect methods of work and means for improvement, both in the material and personnel on the station.

" He should consult and freely discuss with the warrant officer how work is to be done, results desired, capabilities of men and methods of improving them; in order that the best opinion of the two combined, may be put into practice.

" He is the inspector for the navy yard work done on the station.

" The assistant engineer officer on a station is responsible

for: general condition, cleanliness, good order and discipline; periodic inspections and tests; hull-book entries; station records, as directed.

"The Warrant Officer on the Station.

"The warrant officer is responsible for the following:

"The actual condition of the apparatus on the station.

"The performance of all cleaning and repair work on the station.

"The keeping of station note book of repairs.

"The assignment of jobs to the men.

"Custody of equipage drawn out on station.

"He is to be guided in his work by suggestions and directions received from the commissioned officer on the station. Orders to do work and the manner of doing it, will be issued by the engineer officer or senior assistant. These orders may be given via the engineer officer on duty or direct. Orders, disabling the machinery or affecting the routine work, or operation of machinery will be given through the officer on duty.

"General.

"Orders to do work on the station may be given to either the commissioned or warrant officer on the station. Both officers are to be apprised of such orders as soon as possible. An order to do work is to be regarded as an order to the station.

"In the absence of either of the officers on a station, the one present will attend to any duty pertaining to the station.

"It is the intention that the two officers on the station should consult each other about all important matters and to aim at assisting each other in securing the best work and efficient condition of the apparatus and personnel on the station.

"An essential feature of the officers' work on the station is the instruction, training and looking after the men on the station. This work is to be done by the two officers on the

station working together. It should be taken into consideration that the warrant officer is practically a fixture on the station, and seldom subjected to calls for other duty, while the commissioned officer is subject to calls for duty on deck and likely to be changed more frequently, hence the intimate direction of the actual work must fall more largely to the warrant officer."

7. Arrangements other than the above have been made on individual vessels with very successful results. In any case there are certain officers, one or more, assigned to each repair station. On some vessels the dynamo plant is made a separate repair station; on others, the machine shop. Sometimes there are two boiler-room stations, sometimes two engine-room stations.

III.—JUNIOR ASSISTANTS.

8. On large vessels several junior ensigns are usually assigned to the engineer department who have no previous engineering experience. These officers are usually given a definite course of note-book work, are assigned as an additional officer on one of the repair stations, stand junior officers' watch in engine and boiler rooms, and are given certain special duties such as making water tests; making economy inspections for waste of water, power, lighting, etc., about the vessel; and other special work such as will give them engineering knowledge and experience.

As soon as they demonstrate sufficient capability and familiarity with the engineering duty they are assigned to take day's duty and later watches at sea.

9. The following is a course of instruction for junior officers. Another can be found in the JOURNAL OF AMERICAN SOCIETY OF NAVAL ENGINEERS for November, 1906, page 1214.

"Engineer Officers Under Instruction.

"Officers will be assigned to the engineer department for a period of six months. In order that they may have every opportunity of perfecting themselves in engineering, they will

not be required to perform any duty other than that in connection with the machinery plant, except that of their battle stations.

" The period of 6 months will be divided up as follows:

" Main engine station.....7 weeks;
" Boiler station .....7 weeks;
" Auxiliary station .....7 weeks;
" Data, records, log, etc. .....5 weeks.

" Each will closely follow all work in progress on his station, and upon its completion will write up the description required for the ship's records.

" He will acquaint himself with the methods and manner of making repairs and the time required therefor, not hesitating to request practical information from the machinists or enlisted men.

" For the purposes of instruction they will keep watch in the following manner:

" When the ship is underway, regular watch in four will be kept, two hours of which will be passed in the engine room and two hours in the fire room.

" In port, for the first three weeks of assignment to each station, one watch a day will be kept on that particular station. Each day a different watch will be kept, so that at the end of the three weeks' period each watch of the day will have been kept three times, and they will have become acquainted with the routine management of the machinery under all conditions and at all times of the day.

" The one on the main-engine station will keep his watch in the engine room; the one on the boiler station, in the fire-rooms; and the one on the auxiliary station as follows: One week on the refrigerating plant, one week on the evaporators and the fresh-water supply, and one week in the power boats.

"A list of subjects for the guidance of the officers under instruction in studying the machinery plant has been prepared.

"It is required that the entire list be covered during the six-months period. Nos. 2, 7, 12, 21, 28 and 34 will be taken up first. It is suggested that the others be taken up according to the stations they are on at the time.

"In addition to the above it is hoped to establish a course of reading which will form a continuation and amplification of the subjects studied at the Naval Academy.

"At the close of the six-months period a written examination covering the various subjects studied will be given.

"*List of Subjects.*

"1. *Ash-handling gear.*—General description. Description of ash-hoist engines, to include dimensions, capacity and sketch of follow-up-valve control. Description of ash expellers, to include general sketches.

"2. *Compressed air plant.*—General description of entire system. Description of the air compressors, to include dimensions and capacity. Sketch of entire piping system, distinguishing the leads for gas expelling, ashes expelling, and air tools. Sketch to show location of valves and separators and to give sizes of piping.

"3. *Anchor engine.*—General description of the windlass and its engine. Detailed description of manner of operation; this to be illustrated by a sketch showing clutches, etc.

"4. *Boilers.*—Sketch showing general arrangement of boilers in ship. Complete description of a Babcock and Wilcox boiler as installed in this ship, to include principal dimensions. Detailed description of all interior fittings. Detailed description of all exterior fittings. Descriptions to be accompanied by sketches.

"5. *Power doors.*—Sketch showing location of all power doors. Complete and detailed description of their operation, to include description and sketch of motor, system of winding, etc. Sketch showing wire leads from main switch board to each door, with all switches, etc.

"6. *Condensers.*—Description of main condenser, to in-

clude general dimensions, material of various parts, all pipe connections. All attachments. Same for auxiliary and dynamo condensers.

"7. *Distilling apparatus.*—A complete description of the entire evaporating plant. A detailed description of an evaporator. A detailed description of a distiller. Sketch showing leads of all piping, to include steam piping, exhaust piping, fresh-water piping, salt-water piping, etc. Detailed description of the manner of operation of the plant. Sketch to show entire fresh-water system of the ship with all connections to tanks, etc.

"8. *Dynamo plant.*—General arrangement of dynamos. Sketch showing steam and exhaust connections to turbo-generators, as well as to auxiliary machinery in condenser rooms. Complete and detailed description of the turbine, with sketches. Detailed description of the oiling system and the governor, with sketches. Manner of operating the throttle valve and tripping gear.

"9. *Forced-draft system.*—General description of the forced-draft system, to include manner in which firerooms are closed up. Description of the forced-draft blowers and their motors, to include system of winding of latter.

"10. *Feed-water heaters.*—General description and sketch of the feed-water heater, to include dimensions and material.

"11. *Grease extractors.*—General description and sketch of the grease extractor, to include dimensions and material of both main and auxiliary grease extractors.

"12. *Heating system.*—General description of the heating system of the ship. Sketches to show each of the sixteen circuits with all their connections.

"13. *Indicators and gear.*—Indicator connections of main engines, to include method of reduction of motion. Same for each auxiliary fitted with indicator gear.

"14. *Interior communications.*—General (not detailed) description of all connections to engine rooms and firerooms, also other spaces under cognizance of the engineer's department, to include engine telegraphs, fireroom telegraphs, gongs,

call bells, speaking tubes, etc. A complete and detailed description, with sketches, of the time-firing device. Manner of firing using this device.

"15. General description of steam launch machinery, to include boiler, main engine, pumps, etc., with dimensions.

"16. *Lubrication.*—General description of the oiling system for the main engines. Description of oil tanks, to include their capacities and the manner of filling; the latter to be shown by a sketch.

"17. *Magazine cooling.*—General description of the magazine-cooling system. Description and sketch of the cooling box. Description and sketch of the method of regulation of the temperature of the magazines. Calculations as to cooling effect required.

"18. *Main engines.*—General description, to include dimensions and the material of all principal parts. Clearances, both volumetric and linear. Valve settings, to include Zeuner and elliptical diagrams of each valve. Description of assistant cylinders.

"19. *Pumps.*—Description of each of the following pumps, to include principal dimensions and material, as well as sketch of valve gear: Main air pump. Main circulating pump. Main circulating pump engine. Main feed pump. Auxiliary feed pump. Fire and bilge pump. Oil pump. Dynamo oil-cooler pump. Dynamo hot-well pump. Distiller circulating pump. Auxiliary air and circulating pump. Dynamo condenser-air pump. Dynamo circulating pump. Dynamo circulating-pump engine. Evaporator-feed pump. Distiller fresh-water pump. Shaft-bilge pump. All connections for above pumps to be given.

"20. *Propellers.*—Type, material, and dimensions.—Methods of securing.

"21. *Piping.*—Description and sketch of each of the following systems of piping, giving principal dimensions and material: Main steam in firerooms. Main steam in engine rooms. Auxiliary steam in firerooms. Auxiliary steam in engine rooms. Auxiliary exhaust in firerooms. Auxiliary

exhaust in engine rooms. Steam to windlass engine. Exhaust from windlass engine. Steam to steering engine. Exhaust from steering engine. Bleeder piping. Dynamo steam piping. Dynamo exhaust piping. Main feed-suction piping. Main feed-discharge piping. Auxiliary feed-suction piping. Auxiliary feed-discharge piping. All bilge-suction piping. All sea-suction and discharge piping. Boiler-blow piping. Vapor and escape piping. Drain piping for steam lines. Main drain. Secondary drain. Bilge drains. Steam to sea valves. Live steam to receivers. Steam to tube cleaners. Firemain throughout ship. Water service for main and auxiliary machinery. Give location of all expansion joints, and sketch one. Give location of all Macomb strainers.

"22. *Reversing engine and gear.*—Sketch and describe the reversing engine and gear, giving principal dimensions and material.

"23. *Refrigerating apparatus.*—General description of the entire refrigerating system, with sketch showing location of ice machines, cold-storage rooms, scuttle butts, etc. General description of the dense-air ice machine, with the principal dimensions of a three-ton machine. Method of operation. Sketch showing all piping and connections. Temperatures for different classes of provisions.

"24. *Smoke pipes and uptakes.*—Sketch showing arrangement of smoke pipes and uptakes, giving thickness of material, manner of supporting the stacks, armor protection, lagging, etc.

"25. *Shafting and bearings.*—General description of main-engine shafting, to include principal dimensions and material. Sketch showing couplings. Sketch showing each type of bearing—main bearings, thrust bearings and spring bearings. Sketch of stern tube, etc. Method of lubrication.

"26. *Ramming chocks and ties.*—Describe the manner in which the boilers and main engines are secured to the hull of the vessel.

"27. *Separators.*—Sketch and describe the separators as installed in this ship.

"28. *Steering engine and gear.*—General description of the steering gear of the ship, to include all systems of steering. Description of the steering engine, to include principal dimensions. Sketch and description of the transmission gear from engine to rudder. Description of rudder, with dimensions.

"29. Describe the turning engine, giving principal dimensions. Sketch the manner in which connection is made with the main-engine shafting.

"30. Describe the feed and filter tank, giving all connections. Same for dynamo hotwell tank.

"31. Give location of every trap and its use. Sketch and describe each type of trap installed.

"32. *Valves.*—Give the location and use of all the following valves: All relief valves, with pressures at which set. All reducing valves, with reduced pressures. All manifolds, with their connections. All sea valves. Sketch one of each type of the above.

"33. *Ventilation.*—Describe the ventilation of all engineering spaces.

"34. Write a complete and detailed description of the manner of raising steam and preparing the marine engines for use. This to include the opening of every valve, and the time and manner of conducting every operation.

"35. Take a complete set of cards for one main engine. Make the combined card, neglecting the clearance differences and taking them into account. Make the crank effort curve.

"36. Discuss the balancing of the main engines of this vessel, making the necessary calculations."

10. *Boiler-Water Tests.*—One of the ensigns under instruction on boiler-room station is usually assigned the duty of making water tests, required by Instructions and Regulations. Special instructions as to records, etc., are made on each vessel. It is desirable to have some convenient space fitted up as a *laboratory* where water-test, oil-test, and other special testing outfit may be kept and arranged in such manner as to facilitate making tests

The record of tests is kept in a book or file which is usually kept in office available for consultation by engineer officers, and from which directions as to use of boiler compound, blowing boilers, making examinations of condensers, distillers, etc., can be made, and entries on boiler record sheet or other data sheets taken.

IV.—CHIEF PETTY OFFICERS.

11. *Chief Machinists' Mates* are assigned to sub-stations of the department. On capital vessels the following distribution generally holds—one to each of the following stations: Starboard engine room; port engine room; boiler room; dynamo room and outside piping and auxiliaries; machine shop; steamers, evaporator room and ice machines. Sometimes the distribution on auxiliary station is differently made. In case more chief machinists' mates are available, steamers and motor boats are made a separate sub-station. Extra chief machinists' mates are assigned as second on sub-stations.

The chief machinist's mates in charge of sub-stations distribute the work among the forces under them and are directly responsible to the officers in charge of the station for all work done and for the general condition of the sub-station, both as to personnel as well as material.

Chief machinists' mates take day's duty in port, and when on duty are, in general, responsible to the engineer officer on duty for carrying on of routine matters in the engine room, and are available for calls during their tour of duty.

The chief machinist's mate on duty should be present at 7:30 P. M. inspection to receive night orders or any other special instructions.

12. *Chief Water Tenders* are assigned, one in charge of each of the subdivisions of boiler-room stations. Each is responsible for his own section on watch in firerooms and for the condition of his boiler-room station.

Chief water tenders will stand watch with their own section.

When on watch at sea he supervises the firing of the boilers, sweeping tubes, giving bottom and surface blows, cleaning

fires, trimming of ventilators, striking down coal from top bunkers, operation of feed pumps and feed heaters in fireroom, the regulation of air pressure when under forced draft, the pumping of fireroom bilges, and control of steam. He will recommend changing of time-firing device to officer of the watch, and report any derangement of the time-firing apparatus. He will keep record of the number of buckets of coal used from each bunker, and of such other data on fireroom pumps, pressures, temperatures, etc., as may be needed for the log sheet in the engine room.

At "turn-to" and immediately after relieving the watch at sea, he will carefully muster all the men at their stations, reporting absentees to the log room in port and to the officer of the watch at sea.

They will stand "day's duty" in rotation when at anchor. When on day's duty they will, in addition to regular duties on their own stations, supervise the auxiliary watch in the fireroom, will take charge of fireroom force during the morning watch when ashes are to be gotten out or special work done, will be present at the 7:30 P. M. inspection of the officer of the day's duty, from whom he will receive the night orders, as to calling of steaming watch, cleaning fires, etc., and will be available generally throughout the day for special work or supervision as may be directed.

V.—STATIONS AND SUB-STATIONS.

Engine-Room Station.

13. This station is divided into starboard and port engine room, a chief machinist's mate being placed in charge of each.

Each engine-room station includes double bottoms, blower rooms, etc., adjacent to and connected with the engine room.

Boiler-Room Station.

14. The boiler-room station is usually divided into substations as follows: *Each boiler room* (or two adjacent ones) in charge of a chief water tender, who is in general charge of

firerooms, double bottoms, bunkers and uptakes connected with his boiler rooms.

15. *Boiler-room Machinists.*—In charge of all machinists' work in boiler rooms. One chief machinist's mate in charge and additional machinists' mates to assist.

16. *Boilermakers.*—For large vessels there are usually two. They will perform such work about the main boilers and such repair work to angle irons, floor plates, gratings in firerooms, etc., as may be directed, and are responsible for boilermakers' tools and outfit.

Brick walls in boilers will be built under their direction.

One will be present whenever steam is being raised, and especially the first time steam is raised on a boiler after having been opened.

In special cases boilermakers will perform such work on steamers' boilers and other stations as may be directed, one boilermaker being detailed for this duty as required. When required, boilermakers stand watch at sea, usually qualifying as water tenders.

17. *Washrooms and Uptake or Locker Spaces.*—It is the usual practice to assign these spaces which do not belong to any particular fireroom to the charge of a *chief water tender* not in charge of one of the boiler compartments. He is given several men besides the detail of one washroom keeper from each section to keep these spaces in order.

The petty officer in charge of washrooms regulates the supply and use of fresh water in washrooms, sees that washroom regulations are carried out and sees that dirty-clothes lockers, etc., are kept in proper sanitary condition, and that proper order and discipline is maintained in and about washrooms.

The washrooms are sometimes placed under boiler room station, sometimes under auxiliary station, and in other cases as a special station in charge of one of the junior assistants.

Auxiliary Station.

18. The auxiliary station is divided into several sub-stations. The following is a typical division used on a new battleship:

Dynamo Room, outside piping and auxiliaries, includes all steam piping outside of machinery space, repair of anchor engine, coaling engine, steering gear, galley, laundry, etc. One chief machinist's mate in charge.

Evaporators and Refrigerating Plant. One chief machinist's mate in charge.

Steamers and Motor Boats. One chief machinist's mate in charge.

Machine Shop. Chief machinist's mate in charge.

Coppersmith's Shop. Coppersmith in charge.

Blacksmith Shop. Blacksmith in charge.

Foundry. Molder in charge.

Ordnance Work. Chief or first-class machinist's mate.

On smaller vessels several of these sub-stations would be combined.

19. *Evaporating Plant.*—This plant is usually in charge of a petty officer (oiler or water tender) and three or four firemen, depending on complement. These men are responsible for operating the plant and for all routine overhauling except mechanical work requiring services of a mechanic. In some cases extra help may be detailed, but it is usually a better practice to have the evaporator-plant detail do all their own work.

Special directions for operating evaporators are given on each vessel. Directions for operating evaporators are given in the following references: JOURNAL OF AMERICAN SOCIETY OF NAVAL ENGINEERS, August, 1914, page 843; February, 1911, page 171; Dinger, page 117; Barton (Stickney), page 355.

20. *Ice Machine Detail.*—This detail is usually made in a similar manner to the evaporator room detail. A petty officer, usually oiler or machinist's mate, is in charge of the operation of the plant and its general condition. He may or may not stand watch, depending on men available.

21. *Machine Shop.*—The machine shop on most vessels belongs to the auxiliary station, but in some cases it is a

separate station in direct charge of one of the commissioned assistants.

One chief machinist's mate is detailed to be in charge of the shop, and other machinist's mates and helpers are assigned. The helpers are usually oilers or firemen who have shown good mechanical ability and are given the detail as a means for acquiring experience in doing mechanical work to fit themselves for the rating of machinist's mate.

When the *machine shop* is separate from the auxiliary station the blacksmith shop, coppersmith shop and foundry should be under the same station officer, so that the repair shop forces can all be concentrated.

Repairs done in machine shop, copper shop, foundry, etc., are operated on a job-order system of some kind. The systems in use are not as yet very well standardized and, owing to the varying conditions, it is difficult and perhaps inadvisable to standardize them. Special shop orders are issued which regulate the manner in which work is to be done, how authorized, precedence of jobs, methods of receiving and sending out work, etc.

To facilitate the receiving and delivery of work it will be very useful to have a designated shelf for incoming and outgoing work. All jobs sent to shop are merely placed on the receiving shelf with tag of directions or job order. Jobs finished are placed on outgoing shelf and are then available for distribution.

22. *Blacksmiths.*—There are usually two blacksmiths in the complement. One will be assigned charge of the blacksmith shop (engineer's part) and of the helpers.

The blacksmith in charge is responsible for the tools and appliances that may be issued him; for the cleanliness and good order of the blacksmith shop; and for the expedition and record of such jobs as may be assigned his force. This is in addition to his own work.

He will have fires lighted in the forge and be ready for receiving new work or to proceed with continued work at 8:15 A. M. every morning except Sunday.

When required, blacksmiths stand watch at sea, and can usually qualify as water tenders.

23. *Coppersmiths.*—There are usually two coppersmiths in complement. One will be assigned charge of the coppersmith shop and of the helper.

The coppersmith in charge will have charge and be responsible for the tools and appliances that may be issued him for use in his shop; for the cleanliness and good order of the shop; and for the expedition and records of such jobs as may be assigned his force. This is in addition to his own work.

When required, coppersmiths stand watch at sea, and can usually qualify as oilers, sometimes as water tenders.

24. *Molder.*—There is usually one regularly detailed molder in the complement of a capital ship. He may be assigned one helper, who will be permanent as far as possible.

The molder will be responsible for the condition of the tools and appliances in use in the foundry; of the cleanliness and good order of the foundry; of the performance and record of such jobs as may be assigned him.

When required, molders can stand watch at sea, qualifying as oilers or firemen.

ELECTRICAL WORK IN ENGINEER DEPARTMENT.

25. *Dynamo Room.*—The dynamo room and its appurtenances is under the control of the engineer officer, who has the services of the electrical gunner for any electrical work. In some vessels four electricians are detailed for dynamo-watch duties. When so detailed they are in and under the control of the engineer department. On other vessels the dynamo-room watch is made up of oilers or firemen first class, the electrician standing watch in distribution room. It is believed that the latter system is thoroughly satisfactory, since the division of cognizance is clearly defined. The oilers are better qualified to operate the machinery and more electricians are available for real electrical work. In small vessels where the switch board is in dynamo room it will no doubt be more advisable to have an electrician on watch, or watches may be

divided between electricians having good knowledge of machinery operation and oilers who have some knowledge of electrical apparatus. In any case the detail can be made in consideration of whether more electricians or more oilers are available.

It is usual to detail one or more electricians to have particular charge of the electrical apparatus in the engineer department, and to make ordinary repairs to fixtures, circuits, lights, portables, etc., in the engineer department. The men so detailed make only minor repairs and adjustments, and in case of any extensive repairs to motors or electrical apparatus these are made by electricians specially detailed from the electrical department.

The electricians detailed for the engineer-department electrical apparatus ordinarily do not belong to the *engineer department,* but are members of the *electrical department,* and under control of the officers of the electrical department.

ORDNANCE WORK.

27. On large vessels it is usual to detail one or more of the machinists' mates exclusively for ordnance-repair work, except that men so detailed are required to stand certain watches so that they remain in touch with the engineer department.

A very satisfactory way appears to be to have the ordnance machinist take his orders for work direct from the gunner or ordnance officer, without reference to the engineer officer, any additional work beyond the capacity of the machinist mate detailed being done by job orders on request of the ordnance officer.

The above method is believed to be more satisfactory than to do ordnance work solely on requests made by the ordnance officer.

ORDERS FOR THE OPERATION OF STEAM LAUNCH MACHINERY.

The following are sample orders actually in force:

28. *Boilers.*—Carry steam pressure between 180 and 200 pounds. Keep bright, even fires, between 5 inches and 6 inches

thick. Fire with light charges of coal, and shut the door again as soon as possible. The steam jet must not be used except in case of emergency. Torching the smoke stack shows poor firing, and will not be tolerated. Torching is due to insufficient air; the fires should be broken up, carried lighter, and, if necessary, at the time the furnace door slightly cracked.

Each boiler must be given a light bottom blow every morning while getting up steam when the pressure is about 60 pounds. Early in the morning, the steamer having been laid up for the night, the sediments in the boiler will have settled in the mud drum, so that is the best time to blow.

Blow tubes once in every twenty-four hours. Boiler stop will be kept closed while at boom, except when bleeding. The boilers must be fired with as much care as the ship's boilers.

The ash pans must always contain water, and be clean of ashes, to prevent grate bars from overheating, burning and warping.

Cleaning fires must be done when there is no possibility of cinders blowing on board. If necessary request permission to shift position.

The fireman must not coal or work the fires when at a landing or gangway where the smoke would blow on embarking or disembarking passengers, or to be a nuisance in any way.

A sample of boiler water for test must be drawn off every Friday morning and carried to the engineer officer on duty. When necessary to preserve alkalinity, solution of boiler compound must be put in the filter box.

In freezing weather keep fires under boilers if there is water in them.

Engines.—All engine bearings must be adequately oiled, but no more oil than is necessary should be used. No oil should ever be used in the cylinders. The piston rods must be swabbed only when absolutely necessary, as such oil ultimately gets into the boiler. Speed of engines must not be changed suddenly, except in emergency, and all unnecessary rack and strain of engines and boilers must be avoided. Open drains as often as requisite to keep cylinders clear of water. Engines will be

given a few turns ahead and astern before getting underway, drains open. The by-pass will be used only in an emergency. Feed pumps will be used on alternate days. After getting underway, pump will be so adjusted in speed that a constant feed will be maintained.

When the steamer is to be hoisted for twenty-four hours, the following work shall always be done: (1) Cylinder heads and valve covers removed; (2) Cylinders and valve chests cleaned and wiped with vaselene; (3) Engine and pumps jacked daily; (4) filtering material washed, dried, and renewed if necessary; (5) all necessary repairs reported to the C. M. M. in charge, who will report to the officer in charge of the auxiliary station.

Each engineer will keep in book or form provided for the purpose a daily record of the coal and water received.

Cleaning.—Bilges and machinery will be kept clean. The engineer will clean the engine, shafting, air pump, feed tanks, etc. The fireman will clean the boiler, feed pumps and bilges.

MESSENGERS.

29. There is usually assigned to the engineer's office a fireman having some clerical ability as office messenger and, when sufficiently proficient, as log writer. Such men are in training for the rating of yeoman.

There is usually a messenger assigned to each steaming section who stands watch with his section. In port two of these messengers take alternate day's duty as office messengers and the other two work on their stations. To have a messenger for the auxiliary watch, a fireman or coal passer is given a regular auxiliary watch in engine room. He not only acts as messenger, but assists the oiler in all other work that may be called for. This engine-room detail is thus a means for training all the coal passers and firemen 2d class in a knowledge of what is required in the engine room and in other parts of the department besides their own immediate station.

The relief messenger on his liberty day is required to be at engineer's office during the forenoon.

On other vessels two office messengers are detailed in addition to the engine-room messenger. This calls for more men. If a proper routine and organization is present and the interior communication system carefully used the need for a large number of messengers should not be apparent.

The following are orders for engine-room messengers on watch underway:

Station Starboard Engine Room.—He will carry messages as directed by officer of the watch, will call reliefs for officers and the watch. He will keep drinking water supplied to engine room; will draw the engine-room watch rations. These are usually drawn at 7:30 P. M. He will assist in keeping working platforms clean, attend speaking tube, etc.

_____ 1914.

To- Chief Commissary Steward.

Please issue ( )

rations to bearer, for watch standing people of the 7th Division for use this date.

_____ U. S. N.

Officer-of-the-Day.

ORDER STEAMING RATIONS.

VI.—OFFICERS IN CHARGE OF STATIONS.

30. Officers in charge of stations are directly responsible to the engineer officer for the care, preservation and efficient condition of everything pertaining to their stations. They shall carefully supervise all repairs to the machinery assigned them, and they shall be constant in their attendance during working hours, unless standing watch.

They will carry out the instructions regarding the inspections, reports, etc., affecting their stations. They will not undertake to make any examinations or repairs to the ma-

chinery that will disable it without first obtaining permission from the engineer officer, and reporting to the officer on duty when the work is about to be started and completed.

They will consult freely with the engineer officer upon matters affecting the efficiency of their stations, and they will keep him informed of the progress of the work and condition of the machinery.

They will supervise the muster of the men on their stations to see that it is carried out in accordance with the instructions.

They will report to the officer on duty all work, repairs, casualties and inspections on their stations for record in the steam log daily at the close of working hours, and they will observe carefully the instructions about keeping the steam log.

They are responsible for the discipline of the men on their stations during working hours, and will report to the engineer officer all men who are careless or inefficient in the performance of their duties.

They will mark all men assigned to their stations once a quarter, and recommend for advancement those whom they deem qualified and deserving. They will instruct their men in the duties of their ratings, and exact of them diligent and orderly performance of duty.

While the general directions and instructions as to what overhaul or repair work required are given by the senior engineer officer or by the job-order system in vogue, the details of the planning of this work, and suggestions as to its necessity and its accomplishment, are left largely to the officer in charge of the station.

All work being done by the navy-yard force will be inspected by the officers of the stations concerned. They will be furnished the J. O. number and specification of the navy-yard work to be done on their stations, and will keep the engineer officer closely in touch with the character and progress of the work. They have no authority over the navy-yard workmen, but are responsible for calling attention of the engineer officer to any defective workmanship, use of inferior

material, or improper conduct on the part of any of the workmen.

Officers in charge of stations should anticipate the necessity for repairs and overhaul work, and should plan their work to obtain the most efficient results. They should endeavor to employ all the force available during all the available time, but should not undertake too many jobs at one time if the jobs are liable to interfere with one another. Only such work as can be properly done in the period assigned should be undertaken. The evidently necessary work should be done as far as possible without waiting to be told to do it, and officers should advise the engineer officer of all repairs, changes or improvements that they deem necessary on their stations.

While officers in charge of stations are responsible for the condition of the machinery, etc., on their stations; and while the officer on duty should not interfere with carrying out work or repairs ordered by them, nevertheless all persons of the engineer department are subject to the orders of the officer on duty, and it is perfectly proper and necessary that he give them any directions that may be required to carry out his orders. Officers in charge of stations will therefore promptly obey any orders or instructions given by the officer on duty, and will make no changes in the condition of the machinery, as to its readiness, without reporting the same to him.

Officers in charge of stations will not use the engine room or office messengers, but will utilize men of their stations for carrying messages. In making reports or inquiries by telephone or voice tube they will require their men to use courteous language and to confine themselves strictly to the business in hand. If they desire men to be excused from morning quarters for work on their stations they will submit a list to the office in time for it to be acted upon.

GENERAL HINTS.

31. *Officer in charge of Station.*—An officer in charge of a station is to be held responsible for all the apparatus and

material belonging to it, also for the character of work performed by the men belonging to that repair station. It is, therefore necessary for him to inform himself of the detailed construction and the methods of operation and repair of all the apparatus, all the requirements of the Naval Regulations, and the ship's regulations in reference to the apparatus.

The general aim in regard to matters of repair and preservation should be to keep all of the apparatus and equipment in the most efficient working condition without the need of outside help. This is more easily accomplished by applying the stitch in time, instead of waiting for things to wear out before any attempt at checking the wear is made. Thus, corrosion should be prevented instead of making provision for renewing corroded parts. Wear and tear should be eliminated as far as possible; all defects should be remedied just as soon as it is possible to do so, and in each case the cause of the trouble removed if any way possible. All remedies and repairs should be thorough and make-shift should be avoided.

32. *Proper Tools.*—An outfit of tools designated to be ample for any work to be done is supplied, but there are often special tools and rigs not in the original outfit, which it is desirable to have. These, in most cases, can be made on board, and when they cannot, steps should be taken to have them supplied by requisition. It is also important to keep a close oversight of the tools, so that they are kept in proper condition and repaired or replaced when necessary.

33. *Supplies.*—It is also essential that supplies of sufficient kind and quantity be kept on hand; to this end the supply available in the storeroom should be looked over from time to time and any deficiencies noted, so that the general storekeeper may be notified by memorandum of the need for obtaining stores and material likely to be deficient.

All stores used on stations will be obtained from the storeroom keepers, on stub requisitions or store-room orders taken from the stub requisition book of the officer in charge of station (in emergency or absence of officer in charge of station, stub requisitions may be drawn by the officer on duty

from the books kept in the engineer's office). Care should be taken in anticipating the need for supplies, and it is well to have the stubs for material required for the day supplied to storekeeper the evening before or during the morning watch, so that delay in issuing same may be avoided.

Hand tools are usually issued on tool checks supplied to all the leading mechanics and petty officers, while certain special tools are kept out on stations on custody receipts.

34. Officers of stations are responsible for all articles of equipage, Title B, issued or kept on their station, and will sign custody receipts for same. Certain parts of the outfit of tools, etc., will be kept in lockers or chests by the chief petty officers or petty officers of sub-stations, who will sign custody receipts for same, to be countersigned by the officer of the station. The officer of the station is responsible for the general condition of all this equipment, will see that it is properly cared for and handled, that losses are checked, and will assist in taking inventory when this is required. When any Title B articles are lost, damaged or unfitted for service the facts should be reported immediately, so that proper steps to secure survey or repair can be made.

35. *Station Note Books and Records* (*see Remark File*).—These are of invaluable assistance. All important matters should be placed in a note book for reference, as such information, properly recorded, may later save a great deal of time and trouble in planning work and determining the necessity for various matters of overhaul.

The station note book should contain a record of all inspections, repairs and alterations made, together with any other useful information of value for future reference.

The books should be carefully arranged and indexed in accordance with the headings used in the engineer's remark file or in conjunction with the job-order system in vogue.

The station note book will be turned in to the engineer officer whenever called for, and is to be turned over to relief when an officer in charge leaves the station.

36. *In Regard to Personnel.*—More depends upon the per-

sonnel and the way it is handled than perhaps anything else. The aim must be to get the good will and interest of the men. This is largely done by fair and just dealing, avoiding unequal distribution of work or rewards, distinguishing between faults of commission and faults of omission, as well as by getting the men to understand that they are working for promotion and adding to their professional knowledge and ability, and that proper exertion will be noted and rewarded.

It is specially essential to exact prompt and full obedience, without unnecessary harshness or nagging, and to keep the laggards and delinquents up to the mark.

Another point is to keep people who do not get along together apart as far as practicable. Always endeavor to maintain as cordial relations among the men as possible, and endeavor to create a spirit to work to the best interest and good name of the department and station to which they belong.

Proper instructions must be imparted to the leading men, and it must be seen to that they work right and direct their helpers and subordinates correctly. The men must be trained to work together and to aim at accomplishing the most in the time allotted.

The supply of information by means of books, catalogues, pamphlets, etc., is a good help, and steps to enable the men to get hold of proper information will be of material assistance. In this the station officer can materially assist his men.

37. *Handling Men and Distributing Work.*—Study the capabilities of men, so that they may be detailed to the character of work that they can best perform.

See that this work is distributed according to the capabilities of the men.

Study each job and examine carefully into how it can be best done; don't go ahead bull-headed and run the chance of doing it in a very round-about way. Stop to consider, get advice and make use of previous experience. Records of work will be valuable in this matter.

See that each man does his proper share of work, and do

not permit the good worker to do the work that should be done by the laggard.

Stimulate a spirit of pride in doing a job well.

Encourage the good mechanics to teach, and show the less efficient how to improve their workmanship.

The object of all management should be to increase output, both as to quantity and quality; to economize by eliminating preventable wastes of time, material and equipment; to reduce labor by increasing labor and machine efficiency. To do these things, or any of them, it becomes necessary to specify what the workman is to do, and how, and in what time he is to do it; to so subdivide work that every workman is doing the highest grade of work of which he is capable (to put a machinist to clean a feed tank is like putting a race horse to a trucker's cart). These things can be accomplished only by assigning work to men individually. To do this we must know what is to be done, how it should be done, and the time it ought to take. This information is secured by analyzing every job, determining the operations necessary, the men and machines that can best perform these operations, and the time required.

38. *Incentives to Effective Work.*—Men usually work only from necessity. To secure a full day's work there must be some reward that appeals to the individual man. In any military service the hope of commendation or the fear of censure operates as an incentive. In addition, so far as the enlisted men are concerned, a powerful incentive to honest work lies in the assurance of just treatment—a square deal—and sure reward in the way of privileges and of promotion. On the other hand, the man who is delinquent should be made to feel the disadvantage of being so, and must be informed wherein he falls short of proper requirements in order that he may take steps to better his performance.

39. *Settlement of Differences.*—As the duties of various petty officers and work on various jobs may sometimes cause interference between the men, it is frequently the province of the officer on duty to decide on these points. In these matters, it is specially advisable to hear both sides, and not take

the view of the men first bringing the matter to the notice of the officer. He is likely to be wrong about half of the time. In making decisions consider the matter impartially and make definite decisions that both sides can fully comprehend. Do not leave the matter in doubt, for that will simply bear fruit in further argument. To properly decide it is paramount that the officer be specially conversant with details of organization, exact knowledge of established methods of procedure, etc. In case of doubt, refer the matter promptly to the engineer officer and get a decision. If you do not know, find out, and do not risk making a wrong decision, which may later have to be reversed. Certain petty officers and mechanics will take upon themselves certain prerogatives which they are not strictly entitled to. When these are harmless, they may sometimes be allowed, but when they begin to interfere with the work or the rights and privileges of other men they cannot be indulged.

40. *Relation Between Officer on Duty and Officer in Charge of the Station.*—The guiding consideration should be one of help and assistance and not one of interference. The officer in charge of a station is responsible for the character of work and general methods of doing work on his station, also with the arranging of the detail of men on any job. He is also responsible for condition of the machinery, state of repair; in other words, the results of the work. Therefore the officer on duty should not interfere with the carrying out of any work ordered by the officer in charge of a station.

However, all men of the engineer department are subject to the orders of the officer on duty, and it is perfectly proper and necessary that he give them any directions that may be necessary to carry out his orders, and especially should he be ready to correct any faulty methods of doing things that have been directed, any loafing or dilatory performance of work, or disregard of safety precautions. Any material change in disposition of machinery, calling off of men for other work, or any matter affecting any job on a station, should always be reported to the officer or the petty officer in charge of the station. On the other hand, the officer in charge of station

must make no change in the condition of the machinery, as to its readiness for service, without reporting the same to the officer on duty.

In this matter it is especially important not to take any personal prejudice into your conduct, but to regard whatever matters that may come up impersonally, and solely from the viewpoint of the proper carrying out of the duty in a way to secure the highest efficiency, not merely of the individual station or department, but also to the best interest of the Navy as a whole.

VII.—WATCH AND DAY'S DUTY.

41. The general directions for engineer watch duty are given in Articles 2031–2034, Naval Instructions.

Watch and day's duty is performed by the assistant engineer officers (qualified commissioned officers) assigned to the engineer's department. Chief machinists and machinists ordinarily do not take watch unless the number of engineer watch officers is reduced below four. The senior assistant takes the forenoon watch at sea and may or may not take day's duty in port, depending on work in hand and number of other officers available for duty.

42. The following are a compilation of orders issued on this subject on various ships of the service:

The Engineer Officer on Duty.

There will be at all times an engineer officer on duty. He will be known as the Engineer Officer of the Watch, when performing duty by watches, and as the Engineer Officer of the Day, when performing day's duty.

Whenever fires are lighted under the main boilers for steaming purposes, duty shall be performed by watches; under other circumstances officers may perform day's duty.

The officer on duty, as officer of the watch or officer of the day, is the direct representative of the engineer officer in maintaining the military and general efficiency of the engineer

department. Every person of the engineer department, whatever his rank or rate, who is subject to the orders of the engineer officer shall be subordinate to the officer on duty. He occupies the same relative position with respect to the engineer department as the officer of the deck does with the ship. He should keep informed of all that is going on in the department, and officers in charge of stations must coöperate with him to that end.

He will perform his duties in a zealous and orderly manner, shall remain in the vicinity of his sphere of duty, frequently inspecting the engines and firerooms, and in port, the entire department; and he shall be in readiness to respond to any call.

He will exercise a close supervision over all persons engaged in running or attending the machinery or boilers in use; shall endeavor to secure the maximum economy in the use of coal, water, oil and other supplies in the engineer department, and will suggest to the engineer officer any measures which will reduce waste, increase the efficiency of the department and promote harmony or contentment among the personnel.

He will exercise a general supervision over all work being done in the department during his tour of duty, but he is not directly responsible for the work done on other stations than his own during working hours, unless he receives orders from higher authority to perform certain work. He is responsible for all work done outside of working hours, not supervised by station officers, and for correctly entering in the log all work that has been done during his tour of duty.

He will require all rules and routine orders to be carefully executed, and shall report to the engineer officer whenever in his opinion the progress of the work or the operation of the machinery in use is not satisfactory.

He will not allow the main engines to be turned over by steam without permission from the officer of the deck, and will report to the engineer officer, when the engines are ready, or when he receives orders from the officer of the deck affect-

ing the disposition of boilers and engines or speeds to be maintained.

He will report promptly to the engineer officer any derangement of the machinery, and shall require officers and petty officers in charge of stations to report to him when they are about to do any work that may temporarily disable any of the machinery, boilers or piping. He shall also require them to report to him when the work has been completed, and when any important machinery is to be started or stopped. When any defects of the machinery in operation are noted he will remedy them as far as possible without delay, and notify the officer in charge of the station later.

The chief responsibility of the officer on duty lies in the following:

1. Seeing that the work of the day is properly done and that all orders given to the engineer department are carried out.

2. That the machinery in operation is operated efficiently and economically and that any changes that are required are promptly made.

3. That all defects or derangements are noted and made good as far as possible.

4. That proper order is kept in the engine and firerooms and other parts of the engineer department.

5. That all safety requirements are rigidly enforced both for safeguarding the machinery as well as the personnel.

6. That engineer's force are promptly and properly turned-to at the appointed times, that no loafing is permitted, and that no one knocks off work before the appointed time.

7. That the department is kept in the proper state of cleanliness, not only by cleaning work, but by causing men to avoid making dirt, or allowing work to be done in an untidy manner.

8. That all men of the engineer's force receive proper instructions for their work and duty.

9. That any mistakes, failure to receive orders, etc., are noted and rectified.

10. That captain, officer of the deck, senior engineer and

officers in charge of stations are properly informed of all matters coming to their proper attention and cognizance.

11. That all material, supplies, etc., are used as economically as possible and only for the proper purposes.

12. That all sources of waste affecting engineer department both inside and outside are noted and stopped.

13. That engineer's log and electrical journal is properly written up, and that all station forms have been properly filled in.

14. That all reports for records are properly sent into the engineer's office or otherwise as directed.

15. That all routine tests are made and properly logged and reported to all concerned.

The officer of the day should be personally present at the following:

Lighting and connecting up of any boilers.
Testing of any boilers.
Testing of any safety valves.
When main engines are moved.
Receive reports of turn-to.
Shifting over of machinery.

He will notify the petty officer or messenger of the watch when he leaves the engine room in order that he may be readily summoned when needed.

Before relieving, the officer going on duty will ascertain from the officer he is to relieve, what machinery and boilers are in use, and whether or not they are working satisfactorily; what machinery is disabled, and what precautions as to securely closing valves, etc., have been taken to guard against accident from open piping or boilers; whether all the watch has been relieved and is present for duty, and what orders remain to be executed. He shall ascertain from which bunkers or tanks fuel is being taken, and from which tanks made-up feed; and whether there are any special instructions to be passed along.

After relieving, it should be the invariable rule for the officer on duty to inspect the entire department and inform himself personally of the disposition of the machinery and what work is going on, and at the same time to correct anything requiring it.

DAY'S DUTY.

43. The engineer officers in port take regular turn at day's duty. It has been found from experience that noon is the most satisfactory time to relieve.

The day's duty should continue from time of relieving, noon of one day (actual turning over of duty being done during the noon hour), till time of being regularly relieved, noon of following day, unless the time is changed by the engineer officer or for the purpose of going into steaming watches. (Another practice is to relieve at 8 A. M.; noon, however, is preferable.)

The officer going on duty should be prepared to relieve at noon, and will report that he is ready to take over the duty at that time to the officer on duty in the starboard engine room; and no officer should consider himself relieved of the day's duty until his relief has reported to him below and until he has regularly turned over the day's duty.

In addition to observing the general orders for the officer on duty he will carry out the following:

At turn-to he will see that the necessary steps have been taken to obtain a careful muster of the men on their stations in accordance with the special instructions for muster.

He will acquaint himself with all work or repairs and make a careful inspection of the department. At the beginning of working hours, and at the end of working hours he will again inspect the department. During working hours he will be where his services are most needed.

He will be responsible for the work done by the auxiliary watches, and will carry out the daily routine of the department.

He will require the chief petty officers on duty to report to him for orders at such times as may be required.

He will excuse any men he may require for night work from turning-to in morning watch. When occasion demands he will require the presence of some of the men of the station in question when yard workmen are on board, to supply information and guard against loss or damage to apparatus belonging to the ship.

He will ordinarily assign working parties for work coming up that is not regularly handled by the station officers. In special cases instructions as to working party required should be obtained from the engineer officer. The detail of working parties should be made in an orderly manner according to rules in force on the vessel. For calls of small odd jobs the auxiliary watch men off watch may be utilized. Outside of working hours working parties should be made up from the duty section or non-liberty watch. If it becomes necessary to call on men from the regular stations, they should be called for from the officers or chief petty officers in charge of the station for the required quota.

In making the assignments it is to be borne in mind that those men whose services can best be spared should be sent, and the officer or petty officer in charge of the station should make the detail whenever practicable.

The engineer officer of the day will, during his tour of duty, make several inspections of the entire department, noting the progress of the work, condition and defects. He should, just before the close of working hours, make a tour of inspection to note conditions and direct as to any disposition or precautions to be taken at the completion of the work for the day, that everything may be secure and ship-shape for the night. Engine-room blowers to be shut down at night in cool weather.

In the evening, between 6:30 P. M. and 7:30 P. M., he should see that all unnecessary watertight doors are closed, bilges pumped out, double bottoms and fresh-water tanks sounded, unnecessary lights out, storerooms secured, and orders posted for the night. He should give the necessary in-

structions for the use of fuel and feed water for running the evaporators and ice machines during the night; for calling officers and men in the morning, etc. He shall report the department to the engineer officer after this inspection and before 8:00 P. M.

44. The following is a guide for the engineer officer of the day, and petty officers on duty in making their inspections:

Is machinery running to best advantage; men on watch attentive? Is any machinery in operation that is not needed? Are there any steam or water leaks that have not been noted or remedied? Have gangs of men at work received full instructions, and do they understand what they are to do? Are any men waiting for orders, tools, supplies, material; or are different gangs interfering with each other? Is it possible to correct this? Are any safety precautions being violated? Are the feed-water heaters and grease extractors in use? The feed pumps should not be run at over 100 feet per minute (piston speed).

In Fire and Engine Rooms.—Note the condition of the feed water in the hot-well; is it perfectly fresh and free from oil, and is it at the proper temperature? If too high (it should not be over 155 degrees F.), evidently some traps or drains are open or leaking, and should be closed or made tight. If too cold, the circulating pumps may be running unnecessarily fast.

Note the temperature on the discharge side of the feed heaters. Has it been raised sufficiently? (It should be at least 210 degrees F.) If not, it may be air bound, or full of condensed water. Open air cock or drain, if necessary, or increase the back pressure of the auxiliary exhaust.

Are the bilges reasonably dry and clean? Is any dirt or soapy water being dumped into them? Is the auxiliary condenser giving a proper vacuum for the speed of the pumps? Improper vacuum is often an indication of air leaks into the drain line.

Are fires in proper condition, and are the men firing properly? Are there any evidences of leaks in the boilers? Is

there an excessive amount of ashes in ash pans, or an appreciable amount of coal in the ashes? Is coal being taken from the proper bunkers or oil from the proper tanks, and is it being properly tallied? Are bunker doors properly secured and being properly ventilated?

Outside Fire and Engine Rooms.

Refrigerating Plant.—Are the refrigerating chambers at the proper temperatures? Are more machines running than is necessary to keep the desired temperatures? Are the machines working smoothly, and are the proper temperatures being maintained? Is ice being frozen in proper time? Are the machines and compartments clean? Are the special instructions being carried out?

Evaporating Plant.—Are proper pressures being carried? Is proper amount of water being made, and are tanks properly tested before sending water into ship's tanks? Are pumps working properly? Are the special instructions being carried out?

Washrooms.—Have they been properly cleaned up at the times required? Are there any indications of waste of fresh water, and are all orders being carried out?

Dynamo Rooms.—What is the lighting and power load? Is it proper for the conditions existing? Are there any unnecessary circuits on? Are the compartments and machinery clean, and are the special instructions being carried out?

Outside of Department.—Inspect slop chutes and crew's heads to see that flushing water is properly regulated and not being used excessively; that machinery started on deck is not kept running needlessly. Inspect galley and pantry steam lines and heater lines for leaks.

Morning Watch in Port.

The morning watch is usually occupied in getting rid of ashes, getting up fuel for galleys and launches, cleaning stations, moving valves and idle machinery, pumping bilges, etc.

This work is usually accomplished by the duty section, or detail, but other sections may be called if necessary. Collect all mess gear used during the night watches and return same to galley. Get ready for the work of the day, preparing tools, getting up floor plates on the day's bilges to be cleaned, etc.

On many vessels there is no general turn-to in morning watch except for special work as above.

Turning-to and Knocking Off Work.

Working hours for all hands are from 8:00 to 11:30 A. M., and from 1:00 to 4:30 or 5:00 P. M. Officers and men should be on their stations on time to insure a prompt "turn-to," which is most essential.

At " knock off" all compartments should be made ship-shape. All stop and throttle valves and exhaust valves of pumps not in use should be closed.

THE WATCH UNDERWAY.

45. *The engineer officer of the watch* is especially responsible for carrying out the orders of the officer of the deck as to the speed and operation of the machinery. He can not relieve himself of this responsibility by delegating it to the petty officers under him and must personally see that the directions are properly carried out.

He should carefully observe the instructions given under the heading " Officer on Duty" in these notes.

Before he takes charge of the watch he will ascertain whether the new watch are all on their stations, and should be informed by the officer going off watch as to the following particulars:

1. What boilers are under steam, and their general condition as to fires, fuel used, leaks, etc.

2. What orders exist in regard to cleaning fires, sweeping tubes, etc.

3. Fuel allowance, and from which bunkers or tanks it is being used.

4. Whether forced draft is on, and any orders concerning it.

5. Whether the blowers are ready for use.

6. The revolutions for the standard speed.

7. The combination of turbines in use. Setting of links.

8. Steam pressures to be carried.

9. What auxiliaries are in operation, and their general condition, especially evaporators, ice machines and fire and bilge pumps.

10. General condition of main engines, and any defects that may have developed, such as hot bearings, difficulty with throttle, small dummy clearances, etc.

11. State of auxiliary exhaust; whether on turbines or condenser.

12. Any defects existing, such as leaks, salt feed water, bad vacuum, etc.

13. What parts of auxiliary machinery or piping are disabled or put out of use temporarily.

14. From where extra feed is to be obtained.

15. Call attention to any orders to be passed along, and give information as to any work going on in the department.

16. Check up condition blank, and see that all entries have been made.

After Relieving.—The engineer officer of the watch should make a careful inspection of the machinery in operation, noting particularly the following:

1. That all men are at their stations and properly performing their duties, and ready to promptly carry out orders.

2. That throttle machinists understand what revolutions are to be made.

3. That steps are taken to stop any steam or water leaks.

4. Whether the best vacuum is being maintained.

5. That the circulating pump is not running too fast. If the discharge from condenser is above 90 degrees F., more circulating water is necessary.

6. Is the best feed-water temperature being maintained, and

is the excess auxiliary exhaust being used to the best advantage?

7. Are any unnecessary drains blowing into feed tank?

8. Is lubricating system working properly, and are the expected temperatures and pressures on bearings being kept?

9. Note clearances in turbines, setting of links on reciprocating engines.

10. Is an excessive amount of extra feed being used? This will indicate steam or water leaks?

11. Is air-pump discharge or water in feed tanks salty?

12. Are the pet cocks used regularly to prevent condensers and feed heaters from becoming air bound?

13. Are more feed or bilge pumps running than necessary to meet the immediate demands, and are bilges dry, and are any running at excessive speed (100 feet per minute)?

14. Is the firing being done in accordance with instructions, and are the fires in good condition?

15. Is the proper routine for cleaning fires being carried out?

16. Is the coal being carefully measured and tallied, and is any being wasted in the ash pans or in cleaning fires?

17. Is it being used from the proper bunker?

18. Is the proper water level being maintained, and do the gage glasses test out satisfactorily? Is the feed constant?

19. Are the blowers being used when not necessary?

20. Are the tubes clean, and are there any leaks in boiler casings noticeable?

21. Are all safety precautions being observed?

CONDITION BLANK.

46. A condition blank is found to be very useful for use in the engine room. These blanks have to be specially prepared on each vessel, and if the engine-room watch is required to enter matters properly, time, trouble, confusion and mistaking of orders is avoided.

A sample condition blank is here shown:

U. S. S. UTAH

_____ 191

CONDITION BLANK

To be kept in Engine Room and passed to Relief.

IN OPERATION		MIDNIHGT	TO	FROM	TO	FROM	TO	FROM	TO
Forced draft blowers Nos.									
BOILERS	Auxiliary								
	Banked								
	Steaming								
	Fuel Oil								
FEED PUMPS	Main S 1-3								
	P 2-4								
	Aux. 1-2-3								
CONDENSERS	Main S P								
	Aux. S P								
PUMPS	Ash Ejector 1-2-3								
	F R F and B 1-2-3								
	S E R F and B 1-3								
	P E R F and B 2-4								
	Por Lub S 1-3								
	Por Lub P 2-4								
	Oil Cooler S P								
	Bu. Circ. S P								
	Fuel Oil Sup. S P								
	Fuel Oil Ser. 1-6								
TURBO-GENERATORS	Number 1-2-3-4								
	Condenser S P								
	Hotwell Pump								
	Oil Cooler Circ.								
EVAPORATORS	Single Effect								
	Double Effect								
	Dist. Circ. Pump S P								
	On Ship's Tanks								
	On Rererve Tanks								
	On Feed Tanks								
ICE MACHINES	Scuttle Butts								
	Ice Box								
	Mag. Cooling 1-2-3								
	Refrigerating								

STEAMING DATA		Mid. to 4	4 to 8	8 to Merid.	Merid. to 4	4 to 8	8 to Mid.
	Carry steam pressure at						
	Standard revolutions						
	Hot bearins						
	Leaks developed						
	Fires cleaned						
	Boilers connected						
	DAILY ROUTINE						
BOILERS	Tested						
	Surface blowed						
	Bottom blowed						
MOVED	Main engine						
	Auxiliary machinery						
	Water tight doors						
	Tested water in feel tanks						
INSPECTED	Steam launches						
	Turbo generators						
	Compartments						
	Bunkers						
	Oil tanks						
SAFETY VALVES	Moved by hand						
	Lifted						
CHECKED	Oil account						
	Coal account						
	Tools						
TESTED	Pumps						
	Telegraphs						
	Whistles and Siren						
BILGES	Cleaned						
	Pumped						
	Strainers cleaned						
	Heating circuit numbers						
	Grease extractor cleaned						
	Cleaned fires No.						
	Blew tubes in boilers						

IN OPERATION	Midnight	To	From	To	From	To	From	To
Feed heaters S - P								
Reserve feed from								
Coal bunkers								
Steam cutters								
Air compressors								
Coaling engines S P								
Ash hoists 1 2 3								
Anchor engine								
Engineer Officer on duty								
Chief Watertender on duty								
					Machinist Mate on duty.			

WORK IN PROGRESS

WORK COMPLETED

TIME	ORDERS RECEIVED	FROM

MACHINERY, VALVES, ETC., NOT TO BE MOLESTED	BY ORDER OF

NECESSARY REPAIRS ORDERED

ORDERS TO CALL	No.	DECK	AT

POINTS IN FUEL ECONOMY—FIREROOM.

47. On coming to anchor care should be taken to see that the fullest steam-making ability of the fires on the grates is utilized. So long as the fire that is to die out will make steam, allow it to do so, and hold back on the boilers that are to be kept for auxiliary service.

When word is received that anchor will soon be dropped the fires should be kept light, and, if heavy, allowed to burn down, and no more new fuel put on than that just necessary to keep them in proper steaming condition.

Particular attention is to be paid to reclaiming coal that has become mixed with the ashes. This should, as much as possible, be raked clean and burnt. Even if some ashes are mixed with it, there is the chance of getting something out of the fuel.

In cleaning fires special care is to be taken that little or no good fuel is raked out. It is only clinker and ashes that should be gotten rid of. The good fuel should be carefully winged over, and where some is unavoidably hauled out it should, when practicable, be put back in the furnace.

Every steam or fresh-water leak should be stopped as soon as possible, no matter how small. The aggregate of small leaks, most of which are hardly noticeable, amounts to about 1,500 gallons a day on a large vessel and means the expenditure of about a ton of coal per day.

POINTS IN ECONOMY—ENGINE ROOM, IN PORT.

48. Avoid and promptly stop all steam or fresh-water leaks.

See that no more auxiliaries than are actually necessary at the time are in operation. Pumps run at proper stroke.

Do not run extra pumps, air compressors, etc., unless it is known that they are needed for some purpose.

See that feed temperature is maintained at or above 210 degrees F.

See that trap discharges do not keep an excessive temperature in feed tank.

The temperature of feed tank should not go above 155 degrees F.

POINTS IN ECONOMY—ENGINE ROOM, AT SEA.

49. Keep up feed temperature.

Keep highest possible vacuum.

See that there is proper pressure on gland steam. Operate no more auxiliaries than are necessary. Do not call for putting on blowers if speed can be made by temporary shutting down of evaporators or ice machines. Avoid necessity for starting an extra dynamo. Put auxiliary exhaust to turbines in on the side that will tend to equalize powers on different shafts.

See drain valves of turbines closed.

See that unused throttles and other connections to turbines which are not in use are securely closed off.

For Reciprocating Engines.—See that proper cut-off is set, drains shut off when not needed, all possible stuffing-box leaks stopped.

DUTIES OF PETTY OFFICERS, AUTHORITY, CHAIN OF COMMAND, ETC.

50. In order to fix responsibility and insure correct naval discipline there must always be a regular chain of command by which authority is vested in the senior petty officer present.

The officer on duty is the senior in authority under the engineer officer (or senior assistant). Authority and responsibility of persons *on watch*, under the officer on duty, is fixed, as follows:

1st senior person on watch in engine rooms.

2d senior person on watch in firerooms.

Under them come the seniors on watch in charge of compartments, or of machinery and boiler units. They will require all persons under their authority to relieve promptly at the proper time, and they are responsible for the accurate muster and discipline of all persons on their stations. They will report to their immediate seniors the result of muster as

soon as possible after coming on watch, and whether the machinery or boilers are in satisfactory condition.

No one on watch will leave his station without permission from his immediate superior.

Each person upon relieving will listen attentively to the orders turned over by the person he is about to relieve, and will check up the condition of the machinery or boilers to see that it is as reported. Upon being regularly relieved each person will report to his immediate senior the fact that he has been relieved, together with the condition of the station as turned over by him to his relief.

In port, the chief petty officers on duty are the direct representatives of the officer on duty, and are responsible to him for the discipline and proper operation of the engineering plant of the ship during their tour of duty.

All men should consider and realize that they are a particular unit in a large organization whose success depends on the manner in which each unit performs his allotted task. Team work is necessary. All orders should be quietly and quickly obeyed, and all orders should be given through the proper channels in clear language. Each petty officer of a station or substation is a cog of authority, and to secure smooth working the necessary order must pass through him, and the men on the stations must fully comprehend that the petty officers have full authority over them and that their orders must be respected in every way.

THE AUXILIARY WATCH.

Two methods in use are given.

51. *First Method.*—There will be four auxiliary watch sections, made up as far as possible from men stationed in the fireroom of the boilers in use, and from the engine room men belonging to the same mess as the men on watch in the fireroom, the idea being to have as few "late messes" as possible, and not to employ men from the cold firerooms.

Watches will be four hours long, except the 4:00 to 6:30 P. M., and the 6:30 P. M. to midnight watches.

The auxiliary watch will be changed about every seven days, at noon on Saturday (or Monday).

Men having the forenoon watch may go on liberty after 1:00 P. M., and will go on watch again at 8:00 A. M. the following morning. This section coming off watch at 12:30 will remain off watch 24 hours, whether liberty is granted or not, and the other three sections will stand watch in three until 8:00 A. M. next morning.

52. *Second Method.*—A new auxiliary watch each day, taken from the watch, starboard and port, not on liberty. Watches are assigned in regular order through each rate and are posted one day ahead. This system has the advantage of distributing all watch-standing work evenly and of not in any way interfering with liberty. It has the disadvantage of shifting watches continually and also of changing the fireroom working gang from day to day instead of from week to week.

Under this system, the auxiliary watch turns-to, except men who have the 4–8 A. M. watch.

53. *Duties of Auxiliary Watch.*—The senior man on watch in the engine room is responsible under the engineer officer of the day and chief petty officer on duty, for operation of the engine-room machinery and for the starting and stopping of all other machinery in the department; of water in feed tanks; distribution of evaporator water into double bottoms; for making proper entries in rough log concerning temperatures, machinery in use, fuel and water account, and for carrying out such orders as he may receive from the engineer officer of the day or officer of the deck.

The second man in engine room will assist the senior in such work as he may direct, and will act as the officer of the day's messenger, and will not be used by any other persons.

The *water tender,* or person acting as such, will have charge of the operation and economical use of auxiliary boilers, pumps and other machinery in the firerooms. He will keep a record of the amount of fuel used from the various bunkers or tanks and will report same to oiler on watch, with such other data as may be required for the log or other records. He will

observe such orders or directions as he may receive from the engineer officer of the day, C. P. O. on duty, or senior man on watch in the engine room.

Men standing auxiliary watch are required to keep steaming firerooms and engine rooms clean and in order during their watch.

VIII.—OFFICERS IN CHARGE OF SECTIONS.

54. The officer in charge of a section of the engineer division acts as a divisional officer for the men of his section. As such he has charge of the section when mustered at quarters, sees to the personal appearance and cleanliness of the men and to the proper care and condition of their clothing and bedding.

The officer in charge of the section should also specially watch over the general conduct of the men of his section, and should give the men personal advice and information and aid them in any difficulties and assist them in the way of professional information, etc.

It is most advisable for the officer in charge of a section to give men, especially those newly enlisted, general instruction in regard to service matters. Coal passers newly enlisted are often entirely ignorant of all naval ways and usages, and a little systematic instruction and information given by the officer of the section will help them to keep out of difficulty, to become more efficient, more obedient and amenable to discipline, and to become much more useful members of the ship's company.

Among the matters to be taught are:

General matters of ship's and service regulation.

Status of petty officers and their relation to other men and to the officers.

What the conduct of men should be and what steps they must take to better themselves in the service and obtain promotion.

What work they should study and how they may best apply knowledge or ability in any trade for their own betterment.

A personal interest should be taken in the men, in order to establish those relations between officers and men which make

best for contentment and ambition on the part of the men which will enhance their respect for their officers and conduce to discipline and prompt obedience without hardship or severity. The importance of this matter and its thorough consideration by the officers cannot be too deeply accentuated.

MUSTER.

55. Men should be mustered by the chief petty officers in charge of the stations or of the squad or unit of organization. It is important that the muster be made in a prompt, orderly and military manner, and any tendency on the part of the petty officers or junior officers to be lax in this respect should be promptly corrected.

When in Port.—Messmen, auxiliary watch, men not required to turn-to, steamer relief crews, etc., will muster at quarters with the rest of the ship's company. The senior petty officer usually makes the muster from muster list supplied by the engineer's office. This muster is usually supervised by the engineer officer on duty or by one of the junior officers specially designated.

All other men are mustered at their stations at turn-to. The muster is made either from muster lists kept on station, absentees being reported to the engineer's office or to the officer on duty, or by means of muster books, which are sent back to the office with the absentees noted. This latter is the better system, since it is automatic and preserves a record. The muster books, which are kept corrected in the office, are distributed by a messenger shortly before turn-to and collected ten minutes after turn-to. The engineer's yeoman then makes a list of those absent, checks this with sick list, absentees and prisoners, and sends the list of unaccounted for, to the officer on duty to be located, reported, absent, late, etc.

On Saturday and Sunday quarters all men except those on watch or specially excused (names having been handed in by officers in charge of stations) are mustered at their regular stations for quarters.

At Sea.—All men not on watch or working below muster at

quarters at their regular stations for quarters under their section or divisional officers.

Men on steaming watch muster at their post of duty on relieving. Watch lists are usually supplied, one in engine room, one in fireroom, with a copy of his own section for each chief water tender.

During quarters at sea, section officers should utilize the opportunity for giving men of their sections instructions and advice, correct men who are improperly dressed or preserve an improper bearing, and utilize the period for imparting any general knowledge, explaining orders, instructions, work to be done, etc., and, in general, to acquaint themselves with their men, correct defects and deficiencies and distribute information.

Correct muster lists should be kept in the engineer's office and taken out shortly before and returned immediately after muster by the senior petty officer of the squads or section concerned. Sometimes a muster list is kept by the petty officers, but the accuracy of these lists is in many cases doubtful. If the muster lists are kept in the office they can be kept corrected and responsibility is easily placed.

56. *Section Officers* are required to be present at quarters for muster and will be responsible for the correct muster, military bearing, cleanliness and neat appearance of their sections. The movements of the men at quarters should be made strictly in accordance with the Navy Drill Regulations. They should endeavor to impress upon officers and men of their sections that while the engineer's force is excused from most of the military drills, it is nevertheless part of a military organization and should always maintain a proper military bearing and behavior.

They will be present with their sections at inspection of bags and hammocks and at issue and turning in of same. They are required to see that men of their sections have complete outfits of bedding and clothing, properly marked and kept in strict accordance with the uniform regulations. They will sign money and clothing requisitions for the men of their sections and witness issues of same as required. A good practice

is to have a section box for each section, in the office, from which men can gather and deposit requisitions, etc., thus avoiding necessity for men coming to officers' rooms or searching for them.

In carrying on their divisional duties they should use men and petty officers of their own sections, and not impose any of these duties on the engineer's office force.

57. *Clothing Bags and Hammocks.*—The chief petty officers in charge of the squads should be trained to take the responsibility of instructing the lower ratings in the proper care of their clothes, persons, etc. This is an important matter often lightly considered.

At any inspection allow the men who have their belongings in proper order to go as soon as possible.

Make delinquents repair deficiencies then and there.

If at any time a man shows indications of improperly keeping his clothes or person, call for his bag and have it inspected.

Dirty clothes lockers should be inspected at irregular intervals.

In general, put a premium on a man keeping himself and his outfit in order.

IX.—SOURCES OF KNOWLEDGE.

Books of Reference, Etc.

58. An officer newly assigned to engineering duty is likely to inquire what books, etc., should be read to secure a practical grasp of naval engineering duties.

On some vessels a regular course of study, investigation and note-book subjects is prepared, and the officer can thereby be guided. (See under par. 9.)

Note all matters kept in engineer's office.

The first thing to do is to obtain a good grasp of the organization and the names of all the responsible officers and petty officers, and their detailed duties and responsibility. Read the Naval Regulations and Naval Instructions dealing with the engineering duty and engineering matters carefully. Study

the references mentioned in " General Requirements for Rating Engineer and Electrical Department, page 18."

Get catalogues describing special types of apparatus that are on the vessel and study them carefully.

In seeking information about the department, get it from the officers and chief petty officers rather than from the lower ratings. The lower ratings are likely to give some misinformation and sometimes are not extremely careful as to the information they supply. Furthermore, don't expect the engineer's yeoman to furnish you with technical information. His duties are principally clerical.

59. No better course of study can be recommended than to take the JOURNAL OF AMERICAN SOCIETY OF NAVAL ENGINEERS and the " Engineering Bulletin" for several years back, look over index and mark matters that treat particularly of engineering duties afloat. The following is a list of reference books that will be found of value to officers doing engineering duty. Most of these are usually supplied to the ship's library.

Boilers.

Marine Boiler Management and Construction, Stromeyer.
Marine Boilers, Bertin and Robertson.

Electrical.

Electrical Engineering,, Rosenberg–Raymond.
Electrical Engineer's Handbook, Foster.
Dynamo Electric Machinery, Thompson, S. P.
Motor Troubles, Raymond, E. B.
Storage Battery Engineering, Lyndon, L.

Gas Engines.

Internal-Combustion Engines, Güldner.
Gas, Gasoline and Oil Engines, Hiscox, S. D.
Marine Gas Engines, S. B. Clark.
Internal-Combustion Engines, Carpenter & Diedrichs.

General.

Jane Year Book, Engineering Notes.
Brassey Year Book, Engineering Notes.
Lloyds Rules and Regulations, Yearly.
Rules of American Bureau of Shipping.

Marine Engineering.

Marine Engines and Boilers, Bauer & Robertson.

A Manual of Marine Engineering, Seaton.

Marine Engineering, Tompkins, A. E.

Pocketbook of Marine Engineering, Seaton–Rounthwaite.

Miscellaneous.

Applied Mechanics, Cotterill, J. H.

Centrifugal Pumps, Lowenstein–Crissey.

Corrosion and Preservation of Iron and Steel, Cushman–Gordon.

Elements of Machine Design, Unwin.

Engineering Mechanics, Offley, C. N.

Experimental Engineering, Carpenter.

Naval Construction, Robinson, R. H. M.

Speed and Power of Ships, Taylor.

Propellers.

Propellers, Marine, Barnaby, S. W.

Screw Propellers, Dyson.

Refrigerating Machinery.

Refrigerating Machinery, Leask, A. R.

Refrigerating, Heating and Ventilation on Shipboard, Walker, S. F.

Thermo-Dynamics.

Thermo-Dynamics of the Steam Engine, Peabody.

Practical Thermo-Dynamics, Cardullo.

Steam Tables, Marks and Davis.

Turbines.

The Evolution of the Parsons Steam Turbine (Alex Richardson).

The Marine Steam Turbine, Prof. J. H. Biles.

Design and Construction of Steam Turbines, Martin.

The Steam Turbine, Stodola.

Marine Steam Turbine, Bauer and Lasche, translated by Swallow.

X.—THE ENGINEER'S OFFICE.

60. The engineer's office is the headquarters of the engineer department, and is the repository of the correspondence, files, records, drawings, data, forms and stationery.

All assignments of the personnel to stations, watches and special duties are made here, and all changes in the watch, quarter and station bill are immediately posted by the office force.

Books, Records, etc., in Engineer's Office.

61. There are a number of books, files, etc., kept in the engineer's office. The most important of these are kept in the same manner on all vessels, but there are various other records that are kept differently on various vessels.

The following are definitely required by Naval Regulations and Instructions and Departmental Orders, and should be kept in a uniform manner. The notes and explanations are those believed to be the best general successful practice.

Log Book; kept in accordance with instructions (see paragraph 76). Rough sheets to be kept for about six months and then destroyed.

Boiler Record Sheets.—These are really part of the log. Rough sheets are usually kept in a folder and entries made from day to day by the senior assistant or officer of boiler-room station. Smooth copies made at end of quarter and sent in with log.

Vessel's Performance Curve.—Gives speed—horsepower, revolutions, fuel consumption and knots per ton from actual performances. Made on vessel. A smooth corrected copy sent to the Bureau of Steam Engineering and Fleet Engineer with 2d quarter's log.

Electrical Journal.—To be kept in accordance with instructions. Rough log sheets will be kept for record.

Repair Book.—To have entries made when any navy-yard job order has been completed, and to be specially checked up at the conclusion of each visit to a navy yard.

Engineering Competition Forms.—To be made out in accordance with directions, copies retained for data and information.

Blue Prints of Drawings.—Supplied when vessel is commissioned; kept in proper drawers, new additions to be care-

fully indexed in the index book provided and alterations noted on drawings. Electrical drawings are kept separate. Steamer and motor-boat drawings not originally supplied but can be obtained on request.

Remark Book and Remark File (See paragraph 79).—To be kept available for reference, and entries made according to system adopted on vessel.

Machinery Specifications.—Corrected copy supplied when vessel is commissioned.

Booklets of Machinery Plans.—A number of copies supplied.

Booklet of Hull Plans.—A number of copies supplied.

Copy of Report of Preliminary Trial.—Includes speed and standardization curves and data and synopsis of machinery data.

List of Spare Parts and Outfit.—Supplied by contractor.

Confidential Bulletin of Engineering Information.—Issued by the Bureau of Steam Engineering, from time to time.

Bureau of Steam Engineering Standard Sheets (Blue print copy).—If not on board should be secured from Bureau S. E.

Specifications for Engineering Supplies and Material.—To be kept corrected, by obtaining latest specifications as issued.

Instruction for Care and Preservation of Boilers.

Instructions for Boiler-Water Testing Outfit.

General Requirements of Ratings, Engineer and Electrical Department.

Memo. Annual Contracts for Fuel, Oil, Packing, etc.

Rules for Engineering Competitions and Annual Reports of Engineering Competitions.—These annual reports should be carefully studied, as they represent the practice on all the different vessels and give much valuable information.

Noon Coal-Report Book.—Contains duplicate of noon coal report made to captain. Copies of data are supplied on a ship to officer of deck and signal bridge for making noon report.

The Watch, Quarter and Station Bills.—Copies usually kept in book or folder and kept corrected as changes are made. From this the station bills posted in bulletin boards are corrected.

File of Station Billets.—A duplicate station billet of each man in department arranged by rates and numbers. Cards of vacant numbers kept together to be used when numbers are to be filled in. If this file is regularly kept up, the furnishing of station bills becomes an easy operation, since in most cases a name only has to be entered.

Sick List, List of Confined and Absentee List.—Are supplied each day and all placed on a file for reference, and for use in checking up muster.

Copies of Auxiliary Watch Lists, Steaming Watch Lists, Coaling Bills, etc.—Are kept on file for reference until usefulness is gone.

Routine Table.—This table is sometimes a part of the station bill and is usually found in the printed pamphlets giving the rules of the organization and administration of the engineer department. It usually contains the daily and weekly routine and the monthly and quarterly inspections required.

Correspondence Files.—Copies of letters received and sent. It is the present practice to have letters which require signature of commanding officer prepared by heads of departments and sent out by the captain's office, in which a complete file of all ship's correspondence is kept. Copies of such letters prepared, and other correspondence that is not to be filed in the captain's office, is kept in engineer's office; but it is not necessary, nor is it advisable, to duplicate the correspondence files kept in captain's office.

62. The following matters bearing on correspondence and routine reports should be found in engineer's office.

Retained copies of Quarterly Balance Sheet (for fuel).

Retained copies of Quarterly Fuel and Oil Report.

Retained copies of Coal Invoices.

Retained copies of Navy-Yard Job Orders Received.—These should be kept in completed file and uncompleted file, and when fully entered in repair book should be so checked and put in dead file. When *inspection blank* has been signed, copy of job order should be so marked.

RECORDS CONCERNING SUPPLIES.

63. *Retained copy of Requests for Requisitions on G. S. K. on Board.*—These are generally prepared by officers of stations, officer in charge of stores or senior assistant, when need for supplies is noted.

Retained copy of Requests for Survey on G. S. K. on Board.—Article to be surveyed is carefully marked, tagged, etc., and turned in to survey store man.

Summary of Stub Requisitions.—Made each month by G. S. K. From this expenditures are checked. Any unusual expenditure should be investigated.

Copies of Stub Requisitions Issued.—Each station officer is also usually supplied with stub requisition book to expedite issuing of supplies and avoid necessity for coming to office for all stub requisitions. When used up these stub requisition books are retained for record.

Engineer's Allowance List, with inventories and store room notes, location of spare parts, etc.

File of Custody Receipts for Title B articles issued to the engineer department or to any of its members. Or card file of all Title B articles issued showing custodian.

Cleaning Gear Allowance for various stations. This allowance is made up and the amounts indicated are drawn without special request. Avoids the necessity for many special stub requisitions.

The following are usually present in some form:

64. *Order Book.*—This book usually contains all routine orders on various subjects and has orders entered as circumstances cause them to be made. The orders are dated, numbered and initialed in the book by all officers and petty officers concerned. Copies, as may be necessary, are typewritten and posted as deemed necessary. Obsolete or corrected orders should be so marked, and order book should be revised at least every two years.

The order book is kept in the engineer's office in an available place for being consulted.

65. *Daily Order Book.*—A daily order book is an essential matter. This book is sent below to engine room each evening after the senior engineer on board has made his inspection of the department, and is sent to the engineer officer on duty.

It will contain any orders for the disposition of the machinery during the night and orders for work in the morning, and any special instructions as to preparations for getting underway, etc.

The book is usually required to be returned to the engineer's office before 9 A. M. the next morning.

It is believed to be better to have these orders in a book, instead of on loose memoranda, since when in a book there is a record of orders given and there is less opportunity for losing the orders.

66. *Card Record of Men.*—Data of Men's Previous Experiences.—It is usually the case that the men of the engineer department have had experience at trades the handiwork of which may often be required. In order to have a record of this, cards should be filled out giving previous experience, trade, etc. These can be filed under trades or experience and will be found extremely useful in detailing men to stations and in furnishing helpers, and will also help men who have had experience at mechanical trades to obtain details on stations where this experience may be further developed and where their promotion may be more readily secured.

The above mentioned file of experience cards should also show a record of the special duty done by men on stations, such as evaporators, ice machines, steamers, motor boats, etc.; and date of enlistment, leave granted, date of reporting on board can also be entered.

When new men are received their previous experience should at once be entered on the cards, and when leaving ship the experience card should be sent with their enlistment record.

There is some data as to experience on the enlistment record itself, but this is not very complete, and the file cards are a record that can be kept in the engineer's office, easily available for consultation.

67. *Pamphlet of Organization and General Orders for Engineer Department* (Regulations and Instructions of the Engineer Department).—This, on many vessels, is in printed form, on others, in typewritten form or hectograph.

This contains description of the organization, detailed requirements as to duties, and general information as to operation of plant.

A great deal of the information contained in these notes has been taken from pamphlets prepared on various vessels. This is an important adjunct to the organization since it enables methods to be standardized and carried out.

Its most important function is to define the duties of the different officers and petty officers, the division of stations and sub-stations, and the requirement at general drills, exercises, etc.

68. *Order Files.*—Copies of all orders, notices, and memoranda for the engineer department.

This is kept in the engineer's office, on a file board or in a basket, and any memo. for engineer officers, information of interest, etc., is placed thereon. Officers are required to consult this file several times each day to inform themselves of any memorandum added. Important orders or memoranda are required to be initialed by officers or petty officers and then placed on file. Officers newly detailed should read all old orders.

A similar file or book has been found very useful when kept in the quarters of the engineer chief petty officers.

69. *Memo. for General Information.*—This is in the nature of a bulletin prepared by the engineer officer for general information of the department. It will contain any general information, such as work expected to be done, expected movements of vessel, comments on the performance of the vessel, economy, cleanliness, comment on any unsatisfactory conditions. It can be combined with the order file above.

This is prepared primarily for information of officers. It is usual to put one copy in the officers' information file or bulletin

board, on the chief petty officers' bulletin board and on the engineers' bulletin board.

This memoranda may be issued as occasion requires and it will be found that a regular system of doing so will secure much better coöperation and contentment, and will give all hands a thorough understanding of what is being accomplished and undertaken. Sheets are destroyed when out of date.

70. *Repairs Needed.*—These may be entered in a book kept for the purpose or put down on memos and put in engineer officer's or senior assistant's mail basket.

71. The following are usually present in some form:

Data Books.—Curves of performance; reports of trials, including retained copy of engineering competition forms, etc., trials and description of machinery (reprint from JOURNAL OF AMERICAN SOCIETY OF NAVAL ENGINEERS). This can be supplemented by data prepared on the vessel and mimeograph or printed copies added.

Indicator Cards.—Record, usually in a book or file (for reciprocating engines).

Torsion-Meter Record.—Usually in a book or file (for turbines).

Special forms to facilitate computations are usually made up on each vessel, on which logs of all constants are put in, so that calculations can be rapidly made and record of them kept.

Books for Recording Trial Data.—Made out for each station. These are useful to facilitate taking of data and to enable a record being kept. Once prepared they save a great deal of time and ensure data being taken in a uniform manner.

Bunker Coal Book.—This book contains a group of sheets for each bunker. Daily entry of coal taken out or received in any bunker is made. Amounts are corrected when bunker estimates are made. If accurately kept, it gives the amount of fuel in each bunker.

Coal Estimate Forms.—These are used in figuring up bunker estimate. It consists of a list of bunkers with cubic capacity of each and columns for entering volume found on

estimate. The sum of all volumes multiplied by the density gives the total coal estimate. Columns are provided for entering proper density for each bunker. These forms are kept for reference several months and then destroyed. The result obtained from each estimate is entered in the Bunker Coal Book and total result entered in Noon Coal Report Book on day in question for ready reference.

F 8-500 8-12

U. S. S. UTAH

BUNKERS ESTIMATE. NO. 3 FIRE ROOM.

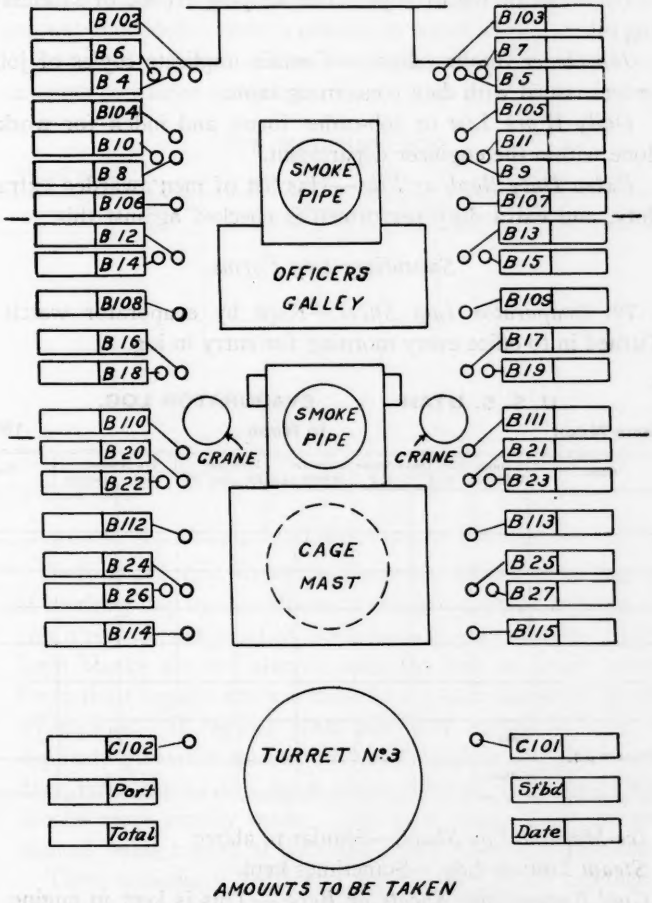
At_____ Date_____ Hour_____

Name of Bunker	Capacity (cubic feet) to lower edge of beams	Actually in Bunker in Cubic feet	Density of contained coal	Tons of coal actually in bunkers
B - 21	3345			
23	3626			
25	2186			
27	3556			
113	2180			
115	2139			
C - 101	1125			
B - 20	3345			
22	3626			
24	2186			
26	3556			
112	2180			
114	2139			
C - 102	1118			
In Boilers				
On fl'r plates				
Total				
Est'mated by				

Coaling Book.—This book is kept as a record of coaling. The coaling report is pasted in each time, also density data and result of coal tally, together with a copy of coaling orders issued. This then forms a complete record of coaling, with all attendant details. A new coaling order is made out by looking at a previous one and making necessary alterations. In this way routine coaling orders are standardized and clerical work reduced to lowest possible limit.

Bunker Diagram.—For the information of executive officer

it is well to have a small bunker diagram of the location of bunkers and chutes, with a space for indicating which bunkers are to take coal and the amount each one is to receive. Several copies of this are made previous to coaling and are distributed to the 1st lieutenant and other officers rigging coaling gear. The presence of this form saves time and avoids a great deal



BUNKER DIAGRAM FOR COALING.

of confusion since each division officer knows exactly where the coal is to go. See Fig.

Water Book.—Showing amount of water distilled for various purposes, and amounts used. Used by engineer officer to check any waste and reduce unnecessary expenditure. Forms may be used instead of book.

Oil Book or file of slips.—For keeping record of lubricating oil.

Job Order Books (slips).—Contain duplicate copies of job orders issued with data concerning same.

Daily Work List or job-order forms and index for work done within the engineer department.

Extra Duty Book or File.—Has list of men awarded extra duty, and extra duty performed is checked against this.

Subsidiary Log Forms.

72. *Evaporator Log Sheet.*—Kept by evaporator watch. Turned in to office every morning for entry in log.

F 120-500 1-12

U. S. S. UTAH - EVAPORATOR LOG.

From Noon ..... to Noon 191

Watch	Name	S Single D Double	xNo. Tanks Water R T	S T	Hours in Service	Pressures 1st. Eff.	2nd. Eff.	Temperature Feed	Disch'ge	Remarks
Noon 4										
4 to 8										
8 Mid.										
Mid. 4										
4 to 8										
8 Noon										
	Total									
x1 Tank 90 gallons.	Gallons									

Ice-Machine Log Sheet.—Similar to above.

Steam Launch Log.—Sometimes kept.

Coal Expenditure Sheets or Book.—This is kept in engine room and filled in each watch. It gives a list of bunkers and

amounts taken from each during each watch. The slips for one day are used for entering data for fuel column in log.

Navigator's Yeoman Reports.—Turned in to engineer's office by ship's log writer. Copy to be attached to rough log sheet.

Water Report, Ship's Tanks.—Made out by captain of hold or water man. Shows water received into ship's tanks and amount expended. Data is entered in water book.

Feed-Water Form.—Gives soundings of all feed tanks and amounts contained in boilers.

F 191-500 11-12

ICE MACHINE LOG

FROM MID. _____ TO MID _____ 191

Mid 4	Name	Machine On	R P M	Pressures		Temperature		Cakes Ice	Remarks
				Comp	Exp	Max.	Min		
Mid 4									
4 to 8									
8 Noon									
Noon 4									
4 to 8									
8 Mid									
One cake - 18 pounds Average									

Daily Work List Report.—These are turned in at the end of working day by the officers in charge of repair stations and give a concise statement of work done on each station. Special form blanks are not always used, but will be found useful. From these reports entry is made in log each day of work done on stations. If regular form pad with carbon is used, the duplicate gives the station officer a complete record of work done from day to day, from which entry in station note book can be more readily made. Job-order blanks may be used instead, being turned in with data when jobs are completed.

These subsidiary log forms can be filed away together or all attached to the rough log sheet. It is the usual practice to keep them for about one quarter and then throw them away.

U. S. S. UTAH

_____ 191

COAL REPORT 12 to 4, 4 to 8, 8 to 12 A. M. P. M.

Bunker	1st hour Buckets	2d hour Buckets	3d hour Buckets	4th hour Buckets	Bunker	1st hour Buckets	2d hour Buckets	3d hour Buckets	4th hour Buckets
B 5					B 4				
7					6				
9					8				
11					10				
13					12				
15					14				
17					16				
19					18				
21					20				
23					22				
25					24				
27					26				
105					102				
105					104				
107					106				
109					108				
111					110				
113					112				
115					114				
C 101					C 102				
*Total					*Total				

*Including coal for galley and steam launches.

Average weight _____ buckets _____ pounds

Coal for galley _____ buckets Coal for steam launches _____ buckets.

_____

Water Tender, U. S. Navy

COAL–EXPENDITURE FORM.

F 131-1m 8-12

U. S. S. UTAH

RESERVE FEED TANKS

NOON _____ TO NOON _____ 191

Comp't	P. M. 12-4	P. M. 4-8	P. M. 8-12	A. M. 12-8	A. M. 4-8	A. M. 8-12
88						
89						
90						
91						
92						
93						
94						
95						
96						
97						
Feed Tanks						
Ext. Feed Used						

Enter soundings in inches.

Bunkers Empty or Level	E - Empty F - Full	12	11	10	9	8	7	6	5	4	3	2	1	Boilers

FEED–WATER FORM.

73. *Miscellaneous Information.*—This consists of catalogues, books, engineering magazines, files of JOURNAL OF AMERICAN SOCIETY OF NAVAL ENGINEERS, etc. These books, etc., should be filed by numbers and card index kept so that any losses can be located. The presence of a proper supply of catalogues, descriptions of apparatus, engineering reports, etc., is a valuable adjunct to the engineer department for the purpose of training men and improving the professional knowledge of officers attached to the department. Special steps should be taken to see that the information available is utilized by all those whom it might benefit.

XI.—ENGINEER'S YEOMAN.

74. The engineer's yeoman is, under the engineer officer, designated, in charge of the engineer's office and of the office force, work and records. He is an extremely important adjunct to the engineer department, and a yeoman thoroughly familiar with the personnel of the engineer's force adds much to the smooth running of the department.

75. The principal duties of the yeoman are:

(1) To write the Engineer's Log from the notes and rough log handed in. (These should be checked and edited by the engineer officer in charge of office, usually the senior assistant.) Since the yeoman is not supposed to be a mind reader or even a trained engineer, he will have to make a smooth copy of the data that is presented. He is not supposed to supply missing parts of logs or to note technical mistakes, but simply to copy and see that the spaces are filled in. The officers writing the log are responsible for what is entered, and not the yeoman.

(2) To keep engineer station bills corrected. This is done under the direction of the engineer officer or senior assistant.

(3) Write official letters and memoranda for the engineer department, and file same.

(4) Enter up various data books kept, such as Repair Book, Remark File, Water Book, Double-Bottom Book, etc. Make up noon fuel report.

(5) Enter data on any special files of information, etc.,

kept in office. Keep files of custody receipts, key list, locker list, etc.

(6) Make out auxiliary watch lists, steaming and work lists, etc., as directed by the engineer officer in charge.

(7) See that musters are checked up and reports of absentees corrected. Keep track of sick, prisoners, etc.

(8) Prepare such liberty lists, leave lists, etc., as may be required, according to the directions of the officer assigned.

(9) Keep track and custody of drawings, special instruments, books, catalogues and other articles and supplies kept in engineer office.

(10) When time permits, to write out smooth copies of officers' and men's requests for leave, transfer, etc. (Special orders concerning this are usually in force.)

(11) See that office messengers carry messages as designated and that office messengers perform their allotted share of the office work assigned.

(12) See that men on watch lists, reports, that have requests approved or disapproved, etc., are notified.

XII.—THE LOG.

76. The Log is a very important matter, and if carefully kept by all concerned is of great value not only to the engineer department, but to the whole vessel, to the fleet and to the Navy Department. Detailed printed instructions for writing the log are issued by the Bureau of Steam Engineering.

Though a very simple matter, logs in many cases are carelessly or inaccurately kept. This is largely due to the fact that the officers do not pay enough attention to this and leave it to the yeoman, who can only copy what is presented to him. Details and data which may appear unimportant or unnecessary to the ship's officers, may prove of considerable value to the Bureau of Steam Engineering.

The watch officers must carefully inspect the entries in the columns and ascertain whether the petty officers collecting the data understand what they are doing. The remarks must be

carefully and clearly written and be complete before the officer leaves his duty.

The officers of repair stations must carefully make their notes as to work accomplished, and these should in all cases be turned in at the conclusion of the day's work. A regular form, daily work list report, for these entries has been found very useful.

The data for auxiliary stations, such as ice machines, evaporators, etc., should be entered on regular subsidiary log forms and turned in at regular definite times.

The log writer should thoroughly understand the instructions for keeping the log. It is sometimes the case that a log writer is allowed to enter things incorrectly for long periods without being corrected. To ensure thorough accuracy the rough log before being written should be carefully edited by one of the engineer officers specially assigned, and turned over to the log writer to make a smooth copy.

77. *Examination of Log.*—This is the most important matter of all as far as the officers interested are concerned. It is the usual rule that the log is ready for examination by 10:30 A. M. at the office. The practice of having a yeoman or messenger take the log around to officers' rooms is a bad one. It makes the officers careless in examining the remarks, errors cannot be checked or corrected as easily and it wastes valuable time.

78. An officer reading his remarks should make sure that they have been entered correctly and that the data for columns and tables for his part of the watch are also correctly entered.

After the watch officers have signed and checked their respective watches it is necessary for the engineer officer or the senior assistant, or both, to carefully check up the log as a whole. It will also be found a useful thing for other engineer officers to read over all the log, thus keeping themselves informed of everything that has been done. The engineer officers should keep themselves sufficiently informed of the entire department to properly take charge of and supervise any station.

Any inaccuracy, inconsistency or oversight in the log should be corrected at once, and not allowed to go in for future modification.

A carefully written, accurate and complete log, promptly signed and handed in each day, is one of the very best indications of a properly organized and administered engineer department.

The log should be absolutely complete and accurate; note of everything should be entered; if this is done there will be little need of extra notes, memo., etc., because everything will be in the log, where it ought to be, and where it is properly authenticated.

All data that has been collected on any performance and operation should be put in the log, so that there is a record of it on the vessel, and in order that such data may be available at the Department. In some logs it has been noticed that the only data entered in remarks on a full-speed trial is "held full-speed trial." This shows an inability to appreciate the purpose of having such things as full-speed runs.

Have consideration for others by so performing your own duty as to coördinate and expedite the work of the department and ship as a whole. Help the yeoman by making log entries complete, legible and concise, and by promptness in writing up the rough log. Do not trust too much to memory, but record data when taken.

XIII.—THE ENGINEER'S JOURNAL, REMARK FILE, OR REMARK BOOK.

79. This is required by Article 2016, Naval Instructions. It is kept in various ways, usually in some loose-leaf or card-index form.

The main purpose of the Journal or Remark File is to give a history of the performance, operation, repair and condition of each part of the machinery, so that it may be known at any time what repairs, alterations, or renewals have been accomplished and the dates in question.

80. When a vessel is delivered, the inspector of machinery where it is built is required to supply a remark book in accordance with the following requirement of the General Instructions to Inspectors of Machinery:

Remark Book.—"The Inspector of Machinery will have kept for each vessel under his inspection a remark book, in which will be entered as they occur a note of any repaired portion of machinery deviating from the regular design, and note of any defects or discrepancies from regular requirements which have been made by proper authority.

"Notes on tests or copy of tests reports of the machinery installed, including hydraulic and steam tests of boilers and piping.

"Brief of results of post-trial examination, including a complete account of any peculiarities of performance observed on the contract trials.

"Records of clearances of principal bearings at time vessel was run on trial. This should include clearance of stern bearings and dummy and thrust clearances in the case of turbines. Such other available information as may be of use to the senior engineer officer of the vessel, such as sizes and kinds of packing used in joints, length of time boilers have been under steam previous to commissioning.

"A subdivision of remark book will have reference to the electric plant and should have such notes on tests of electric plant, including interior-communication system and instruments as are not incorporated in the record of electrical appliances.

"In general, anything concerning the machinery installation will be entered that will be of value to the officers who will have charge of the machinery afloat.

"This remark book will be forwarded to the Commanding Officer when the vessel is commissioned, and report to this effect made to the Bureau."

81. This *Remark Book* should naturally be the beginning and basis for the Journal or Remark Book while vessel is in service.

The following are several successful methods of operating and keeping the Journal or Remark Book:

The basis of any system for keeping a remark book should be simplicity, accuracy, thoroughness, and an antecedent probability that the system of keeping it will be continued at all times, and not allowed to lapse by reason of some officer leaving the department, or stress of unusual duty, etc.

When the ship is placed out of commission the journal should be forwarded complete to the commandant, properly marked as to contents and destination, and a letter of transmittal sent at the same time. Upon future commissioning of the vessel the journal should be sent to vessel.

Method A.

82. Each repair station keeps a *Station Note Book,* either a bound book or loose-leaf, in which all the machinery, appurtenances, compartments and apparatus on the station are assigned under certain designated headings. Each of these items are allotted a certain number of pages in the *Station Note Book.* The officer in charge of station is required to enter, as work is done, any repair, examination, overhaul or other matter of importance under each of the designated headings. This being in addition to the data required daily for the log.

In the engineer's office is kept a loose-leaf file of sheets of the *headings* designated in the *station note book.* Each month the station note books are turned in to the engineer officer, and as much of the entries as is deemed desirable, together with any data or comment from other sources, is typewritten (one or two carbons made) on the sheets in the file. The sheets are grouped by repair stations and the headings alphabetically.

The sheets furnish a complete history of every item in the department. The carbon copy can be sent to Bureau, Fleet Engineer or other place when information is desired.

The *station note books* give each station officer a complete history of everything on his own station and make these

official, so that they are turned over on being relieved from the station.

This system is perhaps the simplest that can be devised, it requires extremely little clerical work and is not likely to fall into disuse in case a yeoman or the officer charged with preparation of remark file should be detached.

The station note books serve a very useful purpose of enabling the engineer officer to keep systematic oversight over station officers as to manner in which repair work is carried out and presents a record of the work done on any station at any time.

With this remark file and the steam log properly kept, a complete and readily accessible history of all work and operation is at hand.

Usually station officers show a very commendable zeal in keeping their station note books neat and supplied with all possible information.

Method B.

83. The Engineer Officer's Journal is bound in a loose-leaf binder, of the Bureau log type, the sheets used being the additional pink sheets of the log. The instructions detailed under the headings of Job-Order Index are observed, each index number being on a separate sheet, and the index pasted in the front of the journal.

The engineer officer, or officer designated by him, edits the work slips submitted by the officers in charge of stations when repair jobs are completed or inspections or tests made, and, with such additional remarks as he thinks proper, enters them under the proper index number on the pink sheets of the journal. It is desirable to enter on these sheets such information from the machinery specifications of the vessel as may be useful when the pages are first indexed.

The journal should be kept in the engineer's office and typewritten daily by the log writer. By the end of the quarter all the entries made in the journal during the quarter are transcribed to pink sheets and filed in the back of the smooth log and forwarded to the Bureau.

Navy-yard work is entered in the journal similarly as other work, but in different colored ink, under the proper heading of the ship's job-order index.

Method C.

84. The Bureau's form NSE No. 169, "Memorandum and job-order pad for use of Engineers," gives a simple and affective means for a job-order system aboard ship. The job orders or any memoranda are made out in duplicate by the engineer officer or senior assistant engineer officer; the original is given to the station officer concerned, the carbon copy being retained on the pad. When the work is completed the original is filled out by the station officer, giving necessary information, such as date of completion, men doing the work, material used, remarks, etc., and sent to the engineer's office. The officer in charge of the office enters the information in the retained pad, on a weekly summary sheet for the log, and posts necessary items in the chief engineer's journal, or remark file. Daily entries are made in the log by the station officers, giving number of job order only, such as continued F 20, completed E 51, etc. The pads are filed in the log room and constitute a permanent and accessible record for job orders and any other orders that are not permanent for the engineer's division.

85. As a matter of assistance in carrying out routine overhauling, the sheets in remark file and headings in station note books should have a short notation of the requirements of overhaul, inspection and test of the particular item in question. As, for instance, *evaporators.* To be scaled after two weeks' running. Interior to be carefully gone over, cement coating renewed and baffles renewed as necessary every six months. All pumps to be examined and overhauled each quarter, etc.

86. *Location of Spare Parts.* The Naval Regulations also require that a record of the location of all spare parts be kept. This is normally best done by having a card index, there being a separate card for each engine or auxiliary. Besides the lo-

cation, the card should show number of spares on hand, when any are surveyed, repaired, etc.

XIV.—THE JOB-ORDER INDEX.

Daily Work Lists.

87. To facilitate the writing up of the log and to preserve a complete record of all repairs and alterations in readily accessible form for future reference, a job-order system and index is used on many vessels.

The machinery, boilers, piping, etc., are designated by suitable numbers and indexed numerically and alphabetically. The *daily work lists,* or reports of work done on the various stations, are referred to by the proper number and submitted to the officer on duty for entry in the rough log at the close of working hours each day. The details of the work are not entered in the rough log, but only the job number is entered there, and the slips are returned to the officers in charge of the stations. When a job is completed a brief of the work done is written up by the officer in charge of the station, from the information contained by the daily work slips, together with such other comment as he may wish to make. These briefs are submitted by him to the engineer officer or person designated by him, and edited. They are then transcribed into the engineer officer's journal by the yeoman, and the briefs returned to the officer in charge of the station *who files them in his station note book.*

The same is done for the navy-yard work on the various stations, except that it is entered under the heading "Work done by Yard Force" in the rough log, using the navy-yard job-order number with the ship's index number in brackets. When entered in the engineer officer's journal the brief of navy-yard work done is written up with a different color of typewriter ink to differentiate it from the work done by the ship's force.

At the end of the quarter the work done is written up on the pink log sheets from the engineer officer's journal, and,

together with a copy of the job-order index, bound with the steam log and sent to the Bureau.

88. The following job-order index used on board the *Michigan* is submitted as a guide for preparing one.

Index Job-Order System.—Engine-Room Station.

100. Air-compresser plant, No. 1.
101. Air-compressor plant, No. 2.
102. Air-compressor plant, No. 3.
103. Air-compressor plant, No. 4.
104. Air-compressor plant, No. 5.
105. Air-compressor plant, No. 6.
106. Miscellaneous.
107. Bilges.
108. Condensers, main.
109. Condensers, auxiliary, including air and circulating pumps.
110. Double bottoms.
111. Engines, main, cylinders, pistons, piston rods.
112. Engines, main, supports and bearings.
113. Engines, main, valves, valve gear and valve chests.
114. Engines, reversing.
115. Engines, turning.
116. Gages.
117. Heaters, feed-water.
118. Indicators and gear.
119. Interior communication, telegraphs, fire-timing device, etc.
120. Piping, steam and exhaust, including valves.
121. Piping, salt-water, including valves.
122. Piping, drainage, including valves.
123. Piping, feed and fresh-water, including valves and grease extractors.
124. Propellers and shafting.
125. Pumps, main air, starboard.
126. Pumps, main air, port.
127. Pumps, main circulating and engines, starboard.

128. Pumps, main circulating and engines, port.
129. Pumps, main feed, starboard.
130. Pumps, main feed, port.
131. Pumps, fire and bilge, No. 4.
132. Pumps, fire and bilge, No. 5.
133. Pumps, shaft bilge, starboard.
134. Pumps, shaft bilge, port.
135. Tanks, feed and filter.
136. Traps and drain lines, including valves, traps Nos. 9 to 19.
    9. Drain from main steam line, starboard engine room.
    10. Drain from main steam line, port engine room.
    11. Drain from auxiliary steam line, starboard engine room.
    12. Drain from auxiliary steam line, port engine room.
    13. Drain from heating circuits Nos. 2, 3, 4.
    14. Drain from heating circuits Nos. 1, 5, 6.
    15. Drain from heating circuits No. 15.
    16. Drain from heating circuit No. 7.
    17. Drain from heating circuits Nos. 9, 10, 12, 14.
    18. Drain from heating circuits Nos. 8, 11, 13, 16.
    19. Drain from H.P. jackets, starboard engine room.
    20. Drain from H.P. jackets, port engine room.
    21. Drain from I.P. jackets, starboard engine room.
    22. Drain from I.P. jackets, port engine room.
    23. Drain from L.P. jackets, starboard engine room.
    24. Drain from L.P. jackets, port engine room.
    25. Drain from reducing valve to steering engine.
137. Valves, sea.
138. Water-tight doors, hatches, etc.
139. Spare parts.
140. Ramming chocks and ties.
141. Relief valves, starboard and port engine rooms.
142. Starboard and port oil pumps.
143. Light and burn oil lamps in compartments C–1, 2, 6; D–2, 3, 5, 6, 7, 8.

Index Job-Order System.—Fireroom Station.

1. Boiler No. 1.
2. Boiler No. 2.
3. Boiler No. 3.
4. Boiler No. 4.
5. Boiler No. 5.
6. Boiler No. 6.
7. Boiler No. 7.
8. Boiler No. 8.
9. Boiler No. 9.
10. Boiler No. 10.
11. Boiler No. 11.
12. Boiler No. 12.
13. Ash-hoist engines, etc.
14. Ash expellers.
15. Bilges.
16. Bunkers, B–1, 2, 3; C–1, 2.
17. Compartments, B–1; miscellaneous, etc.
18. Compartments, B–2; miscellaneous, etc.
19. Compartments, B–3; miscellaneous, etc.
20. Double bottoms.
21. Double bottoms, reserve feed.
22. Gages.
23. Piping, steam and exhaust, including valves.
24. Piping, salt water, including valves.
25. Piping, drainage, including valves.
26. Piping, feed and fresh-water, including valves.
27. Pumps, fire and bilge, No. 1.
28. Pumps, fire and bilge, No. 2.
29. Pumps, fire and bilge, No. 3.
30. Pumps, auxiliary feed, No. 1.
31. Pumps, auxiliary feed, No. 2.
32. Pumps, auxiliary feed, No. 3.
33. Traps, and drain lines including valves; traps Nos. 1 to 8.
    1. Drain from whistle line.
    2. Drain from anchor engine.
    3. Drain from starboard main steam line No. 1 fireroom.

4. Drain from port main steam line No. 1 fireroom.
5. Drain from starboard main steam line No. 2 fireroom.
6. Drain from port main steam line No. 2 fireroom.
7. Drain from starboard main steam line No. 3 fireroom.
8. Drain from port main steam line No. 3 fireroom.

34. Valves, sea.
35. Water-tight doors, hatches, etc.
36. Light and burn oil lamps in compartments B–1, 2, 3, for test.
37. Ramming chocks and ties.
38. Relief valves, heating line No. 1 fireroom.
39. Spare parts, spare boiler tubes, etc.
40. Reducing valve, steam to anchor engine, No. 1 fireroom.
41. Reducing valve, steam to heating circuits, Nos. 1, 2, 3, 4, 5, 6.
42. Reducing valve, steam to heating circuit No. 7.

Index Job-Order System.—Auxiliary Station.

200. Blowers, forced draft.
201. Boats, power motor boat.
202. Boats, power, No. 1 sailing launch.
203. Boats, No. 1 steamer.
204. Boats, No. 2 steamer.
205. Department of Construction and Repair.
206. Department of Ordnance.
207. Engines, steering.
208. Engines, anchor.
209. Gages.
210. Machinery, workshop.
211. Dynamo plant, starboard auxiliaries.
212. Dynamo plant, port auxiliaries.
213. Dynamo plant, No. 1 turbo generator.
214. Dynamo plant, No. 2 turbo generator.
215. Dynamo plant, No. 3 turbo generator.
216. Dynamo plant, No. 4 turbo generator.
217. Dynamo plant, miscellaneous.
218. Plant, evaporators, Nos. 1, 2, 3, 4 evaporators.

219. Plant, evaporators, Nos. 1, 2, 3, 4 distillers.
220. Plant, evaporators, pumps.
221. Plant evaporators, miscellaneous.
222. Plants, refrigerating, ice machine No. 1.
223. Plants, refrigerating, ice machine No. 2.
224. Plants, refrigerating, miscellaneous.
225. Piping, heating system.
226. Piping, miscellaneous.
227. Tanks, fresh-water.
228. Whistle and siren.
229. Traps: and drains, valves and lines, traps Nos. 26 to 32.
    26. Drain from No. 2 evaporator.
    27. Drain from No. 1 evaporator.
    28. Drain from No. 4 evaporator.
    29. Drain from No. 3 evaporator.
    30. Drain from starboard dynamo separator.
    31. Drain from port dynamo separator.
    32. Drain from steering engine.
230. Light and burn oil lamps in compartments A–108; B–101, 102, 115; C–100.
231. Steam boiler forward.
232. Steam boiler aft.
233. Ventilation system.
234. Spare parts.
235. Machine-shop work for fireroom station.
236. Machine-shop work for engine-room station.
237. Machine-shop work for auxiliary station.

XV.—STORES AND STOREKEEPING.

89. *The General Storekeeping System* prescribed in the Navy Regulations and Naval Instructions (see Art. 2231–I, etc.), is carried out, and the following additional rules should be observed by the officers and men of the engineering department for the care and safekeeping of government property.

A corrected copy of the engineer allowance list should be kept in the office, which will show the location of every article

and to whom it has been issued for safekeeping. Duplicate lists or custody receipts will be prepared for each officer or petty officer of the articles assigned to his custody, one of which lists is retained for the office files. By this method all government property can be accounted for at all times and the responsibility for its loss or destruction fixed upon the individual actually in charge of it.

90. *Inventories* are made annually and at such other times as required by the engineer officer; and whenever an officer or other person to whom articles have been issued for safekeeping is detached or relieved he will account for all articles in his possession, and custody receipts will be made out for his relief.

91. *Losses or Damage to Government Property.*—Any person, upon discovery of loss or damage or defects to any part of the material, tools, etc., on his station, will at once report the fact to the officer or petty officer in charge of his station or to the officer on duty, who will bring the facts to the attention of the officer in charge of stores. Articles that have become damaged and are not fit for further use shall not be thrown away, but should be taken to the officer in charge of stores. A survey storeroom is in many cases provided for reception of such articles.

92. *Officer in Charge of Stores.*—The officer in charge of stores for the engineer department will be detailed by the engineer officer. He will have such supervision over the storeroom keepers as may be arranged for between the engineer officer and general storekeeper, and will issue such orders and instructions, subject to the approval of the engineer officer, regarding the issue of supplies, accounting, care and preservation of stores as may be necessary. He will familiarize himself with the regulations governing the general storekeeping system on board ship; with the methods of accounting for property; preparation of invoices, expenditure vouchers, requisitions, summaries, etc., to the end that he may thoroughly *coöperate* with the general storekeeper of the ship.

He will request surveys of articles issued to the department

that have been lost or damaged, for the purpose of establishing and reporting the facts, and will inform the general storekeeper in ample time when supplies under Title "X" are necessary to replenish stock.

93. *Storeroom Keepers.*—There will be detailed four storeroom keepers, one from each section, who, under orders of the ship's general storekeeper and supervised by the officer in charge of stores, are responsible for the issue, care and preservation of all tools and supplies kept in the storerooms and toolrooms, and for the good order and cleanliness of the bilges under them.

In port, storeroom keepers will be available at their stations from 6:00 A. M. to 7:30 P. M., unless on liberty. At sea, there will be a storeroom keeper on watch at all times.

During the evening or morning watch they will assemble and prepare for issue such stores and supplies as are in frequent use, or as may be necessary for the repair jobs for the day, anticipating such demands as far as possible.

The storerooms will be locked, and keys kept in office, when they are not in use.

94. *Rules for Issue of Tools and Supplies.*—Stores are issued on stub requisitions signed by certain officers designated who are permitted to keep stub requisition books. Each stub requisition will show the station to which issued and job-order number in question. The accumulation of material outside of regular general storekeeper storerooms should not be permitted. The regular G. S. K. storerooms should be accessible at all times.

95. *Spare Parts.*—Spare parts are kept in designated storerooms or made fast in assigned places, properly marked, near the machines for which they are spares, and when outside of storerooms are charged to and inventoried monthly by the officers in charge of the stations on which they are used. Their location is entered in the allowance book in the office or on card-index file kept for that purpose.

96. *Tools.*—Certain tools assigned for use on stations are receipted for by the officers in charge, and by them assigned

to the machinists' mates and others, who are responsible for their care. These tools are kept in special lockers or elsewhere on the stations. Other tools for general department use are kept in and issued from the toolroom on tool checks or signed receipts. These, except in special cases, are turned in at the close of working hours daily. When there are several tools of the same kind and class they will be stenciled with different numbers and the numbers noted on the receipts to identify them. Tool checks are issued to certain petty officers, each having a special number.

XVI.—RECEIVING NEW MEN.

97. When new men are received, the engineer officer on duty, or another engineer officer detailed for the purpose, should see that they promptly receive their station billets, and that the general organization of the engineer department is explained to them; *i. e.,* what division and section they belong to, whom their divisional officer is, where their division falls in, their repair station, petty officer in charge, routine of working hours, petty officers to whom they are responsible, how they stand watch, their privileges, liberty, etc. The master at arms should show them their bag racks, lockers, berthing space, hammock netting, wash room, etc.

They should further be given any printed leaflets that may be on hand giving any of the above information (such leaflets are extremely useful), and a short talk by the officer as to what is required of them, what things they must avoid, and where to go for information until they get settled. This talk should be one of general encouragement, and so that they are made to feel that they are really an essential addition to the department, in order that their interest and ambition to do good work and maintain proper conduct be stimulated to the highest degree.

The new men should be taken to their messes, lockers, etc., and then to their officer and petty officer on their repair station, who should have orders to give them clear and careful instructions as to their work, what will be required of them and when they are to turn to for regular duty.

It is extremely important that this matter be properly attended to at the outset, and if done it will avoid much future trouble, besides getting the men started right so that their work will be more efficient.

XVII.—LIBERTY AND SPECIAL REQUESTS.

98. Liberty is usually given by watches (starboard and port), and men are automatically placed on the list when they are entitled to it.

For special requests it has been found useful to have a request book which is available at the engineer's office until forenoon *turn-to,* in which book any man desiring special liberty can enter his name, reasons, etc. This list is vised by a station officer or petty officer and approved by the engineer officer or senior assistant. Approved requests are forwarded to the executive officer and men informed of disapproval of any requests. This system works automatically, and no time is lost by men in making their requests or finding out whether they have been approved.

The book furnishes a complete record of all special requests and repeaters are readily located. Any abuse of special privileges on the part of men can at once be located.

99. *Special Requests.*—It is usually the practice for the senior engineer officer to have a certain designated time at the office, when he will consider personal requests of the men of the engineer division, examine reports, etc. It is usual to make this 11:30 to 12:00 noon, so that work may not be interfered with. The following are orders in force on one vessel.

"*Privileges.*

"*Special Liberty.*—Special requests for liberty will be entered in the special-request book before morning turn-to each day. It is not necessary to see the engineer officer personally about these requests. If they are not granted you will be informed, by messenger.

"*Visiting Parties.*—Can be made out and submitted to the

engineer office for approval. They are ordinarily granted, unless something interferes.

"*Requests From E. O.*—Any man desiring to see the engineer officer concerning special requests, information required, change of station, etc., or any personal matter may do so by coming to the engineer's office between 11:30 and noon each day. Such requests will *not* be considered *at any other time.*

"*Leave.*—Leave will be given during the leave periods as assigned by the Navy Department. Special instructions concerning leave will be given for any particular leave period.

"*Special Money Requests.*—Special money requests will not be approved except for special and unforeseen conditions. Men should draw money required on regular pay day.

"*Remarks Concerning Special Liberty, Etc.*

"There is apparently a great misunderstanding concerning liberty and leave privileges that may be granted by the engineer officer. Rules for going on liberty are made by the commanding officer in accordance with the Fleet and Naval Regulations, and neither the engineer or the executive officer has any authority to grant men leave or liberty that does not conform to these rules.

"When men commit themselves they may be punished with loss of leave or liberty, mitigation of such punishment can only be given by the captain.

"All routine liberty and leave allowed under these rules will be allowed without any need for seeing the engineer officer or executive officer. Special emergency cases will be treated separately.

"When any orders for the time for going on liberty are published, it must be understood that those orders are the orders of the captain of the ship, and that it is not only useless but ill advised and subversive to proper discipline for men to endeavor by personal interview to have such orders modified.

"It must be remembered that the granting of leave and liberty must be done according to rules that the captain con-

siders best for all hands, and though these rules at times interfere with the personal convenience of an individual, they must be carried out without question.

"It will be an invariable rule that men coming on their turn for auxiliary watches cannot go on liberty. Changing watches is a disorganizing and demoralizing practice, likely to result in unfair distribution of duty, and will therefore not be permitted.

"All special requests for liberty must be put down in *request book,* and no other interview with officers is necessary. If further information is desired men will be sent for. They will also be notified when requests are not granted.

"While with fleet, liberty will be given every other day. Men requesting liberty out of watch must give name of man of other watch who will stay on board."

XVIII.—REPORTS.

100. In order that there may be uniformity in handling reports, all reports against any men of the engineer department made by any one in the department should be submitted to the engineer officer for consideration.

It is believed that this is the usual practice. This applies to cases where perhaps only an admonition, warning or explanation is required, and where report to the commanding officer may not be necessary.

It is convenient to have report slips, which are handed in to the engineer officer. The engineer officer goes over the reports, investigates the matter and then finally decides whether report is to be sent to the captain.

101. It has also been found desirable to have an *Engineer Department Report Book,* in which all cases of delinquency, whether reported to the captain or not, are entered. This then serves as a record of cases of probable or unimportant delinquencies that after investigation are not considered of sufficient gravity to be made the subject of formal report to the commanding officer, as well as offenses that are so reported. This record will often be useful in deciding as to giving special privileges, etc.

XIX.—DUTY SECTION.

102. On some vessels there is provision for a duty section. Below is a sample of orders governing this. On other vessels a similar thing is accomplished by having the watch not on liberty perform the services of the duty section. It is believed that this latter plan is more generally satisfactory, since it does not interfere with liberty or any routine matter. The chief petty officers on duty are automatically of the duty section.

"103. There will be a section on duty in port each day known as the Duty Section. Each section will become the duty section in regular turn.

"The object of having a duty section is to provide men at all times for work on all the stations of the department, when other sections are absent, and to give the officer on duty available men for work outside of working hours to carry out the routine work and to make certain routine inspections. No one of the duty section will be allowed to go on liberty.

"The duty section will 'turn-to' at 5:30 every morning watch and carry out such routine work as may be assigned by the officer on duty.

"The C. P. O's. of the duty section will report to the officer on duty at 5:30 A. M., and at 5:00 P. M., in the engine room; receive instructions regarding the work to be done, or inspections and reports to be made. Should the officer on duty require work or inspections of any man after 10:00 P. M. he may excuse him from turning to in the morning watch.

"The officer on duty will require all water tenders of the duty section to inspect their firerooms at the close of working hours, and at 7:00 P. M., to see that they are clean and in order. They will report to the chief water tender of the duty section when this has been done. The latter, at 7:00 P. M., will verify the inspections and report to the officer on duty.

"The chief water tender will make an inspection at 9:00 P. M., and see that nine o'clock lights are out, and that men are "turned in," and will report to the officer on duty the result of this inspection.

"All petty officers of the duty section will remain on their

stations while navy-yard workmen are in the engineer's department. They will guard against loss of or damage to any article belonging to the ship.

"The officer on duty will require a chief petty officer or other person to make an inspection of the engineer's department at 10:00 P. M., and at such other hours during the night as he may deem advisable. During these inspections the person making them shall see that all men on watch are attentive and that the machinery is working satisfactorily; that all men of the engineer's department not on watch are turned in, except those excused by the officer on duty; that no one is turned in or asleep in unauthorized places; that all unnecessary lights are out; that double bottoms, storerooms, sounding pipes, and all bunkers not in use are closed properly; that oil lanterns in engine and firerooms are properly trimmed and burning brightly; that water in ash chutes is closed off; that radiators in use do not become air or water bound; that bilges are dry."

XX.—SPECIAL INSTRUCTION FOR PETTY OFFICERS.

104. It has been found particularly useful to both officers and men to have a course of professional lectures and instruction established. The following is a sample order establishing such:

"Officers designated below will prepare a course of practical instruction for the class of petty officers assigned. The purpose is to give the men a uniform and better understanding of the many more or less involved and intricate matters relating to the work and duties of their rate and to create an incentive on their part for a thorough knowledge of their duties. The course should be thoroughly practical, and be made so that the man can comprehend it and take an interest in what is told him. This instruction will be given at 4 P. M. or some other convenient time on the days assigned and each session should last at least 30 minutes. Other periods outside of working hours may be used at discretion of officers.

"These lectures should include suggestions as to books and pamphlets to be read and directions as to where desirable information may be obtained.

"*Instructions to Chief Petty Officers* as to best methods of handling men, developing loyalty, interest in work and an endeavor to improve their capabilities.

"*Instructions to Machinists' Mates* regarding details of operating machinery, special points in construction and repair.

"*Instructions to Water Tenders,* in regard to firing, care and operation of boilers and training of firemen.

"*Instructions to Oilers,* in general oilers' duties, details of engines and auxiliaries and special points in connection with their duties on the vessel."

XXI.—ROUTINE TESTS AND INSPECTIONS.

105. The Navy Regulations and Instructions require certain daily, weekly, monthly and quarterly tests and inspections.

In the organization of the engineer division certain officers are designated to see that these requirements are complied with.

The officer on duty is responsible for seeing that an entry of the tests required is made in the log. The officers on the several stations are usually responsible for making the tests on their own stations, and certain days for making the tests are usually assigned on a routine table.

An inspection book or inspection report sheet is kept for making entries of weekly inspections of compartments and tests of mechanical devices. The result of weekly inspection of compartments and devices is sent to the commanding officer in accordance with Article 2702, Naval Instructions.

The inspection of compartments and mechanical devices required by engineer officer, Article 2702, Naval Instructions, is made at some time during the week, note of deficiencies made and attention of officers on stations called to these defects.

XXII.—GENERAL OPERATIONS OF MACHINERY.

106. Detailed instructions are usually prepared on each vessel, giving proper steps to take in getting underway, coming to anchor, firing and the routine operation of various aux-

iliary machinery. These detailed instructions are invaluable and their preparation is one of the best methods of developing engineering knowledge.

Some examples of these instructions are given below.

INSTRUCTIONS IN FORCE ON 4-SHAFT PARSONS TURBINE BATTLESHIP.

Preparations for Getting Underway.

Start forced-lubrication pumps.

Start main air and circulating pump 2½ hours before time set for getting underway. (Carry 8 to 10 inches vacuum.)

In starting any pump, first open the drains, then the suction and discharge of the pump, then the exhaust, and, last of all, crack the steam valve to warm up the pump. The steam valve may now be gradually opened and, when the pump is free from water and running well, close the drains. In starting the main circulating pump it must be first jacked over one turn and left in starting position. It may be necessary to put a vacuum on the auxiliary exhaust line before this pump can be started.

Open automatic stop valves, main steam line, and drain maneuvering valves, 2 hours before time set for getting underway.

In opening this valve care must be exercised to crack the valve in order to warm up the line. As the line becomes hot the valve may be opened full, and when full opening is reached, remove the pin and cap on the end of the valve stem.

Turn steam on gland line 2 hours before time set for getting underway.

See counter gear oiled and everything clear for turning, 1½ to 2 hours before time set for getting underway.

Start jacking rotors, with throttle by-passes open ½ turn, 1½ to 2 hours before time set for getting underway.

In case the engines have been standing by for getting underway with the end steam turned on, it will usually not be neces-

sary to jack the engines, as the steam from the glands will furnish sufficient heat to keep the engine warm.

Take out jacking gear 45 minutes before time set for getting underway.

Take counter reading before turning engines.

Inspect oil and water systems 1 hour before time set for getting underway.

Turn engines, ahead and astern each side, with each throttle, ½ hour before time set for getting underway.

Report ready after engines have been tried, ½ hour before time set for getting underway.

Try steering engine 45 minutes before time set for getting underway.

Drain whistle and siren 30 minutes before time set for getting underway.

Test E. R. and F. R. telegraph, etc., 30 minutes before time set for getting underway.

Shift auxiliary exhaust to main condenser when started, 2 hours before time set for getting underway.

F. and B. pump ready 30 minutes before time set for getting underway.

Turn steam on augmentors 10 minutes before time set for getting underway.

After getting underway, close turbine drains.

Shift to cruising combination as soon as both engines are signalled to go ahead at same speed.

Take a set of dummy clearances.

Watch carefully all bearings for signs of heating.

It is important to note that a cruising combination should not be used until it is certain that the steam pressure is high enough to make the required number of revolutions with the combination it is intended to use.

Securing Main Engines After Coming to Anchor.

Give necessary orders to firerooms about disposition of fires.

Close main automatic stop valves.

Shut steam off glands.

Secure anchor and steering engine.

Secure forced-lubrication pumps and oil-cooling pumps about an hour after engines have stopped.

Start evaporators to use up extra steam if not already running.

Shift auxiliary exhaust to auxiliary condenser shortly before main condenser is secured.

Put in jacking gear.

Read and record engine counters.

Open turbine drains, turbines being jacked to drain points.

After about two hours, secure main circulating and air pumps. Air pumps are run this length of time in order to draw all vapor and water out of turbines and thus keep them dry.

Instructions for Working Fires.

The following instructions are hereby issued for the information and guidance of all water tenders, firemen and coal passers who want to become firemen.

The two-number method will be used for working all furnaces, and it will be as follows:

Forward boiler.

3 4 5 1 2 Upper numbers are painted red.
1 2 3 4 5 Lower numbers are brass.

After boiler.

2 5 3 5 1 Upper numbers are painted red.
5 3 1 2 4 Lower numbers are brass.

The system of firing will be as follows:

Suppose the intervals to be three (3) minutes.

No. 1 rings up on the time-firing annunciator then:

(*a*) Push back and level fires of No. 1 brass (lower) number and at the same time

(*b*) Coal No. 1 painted number.

In three minutes from the time No. 1 rang up the firing-interval annunciator will ring up No. 2, which interval will give plenty of time to work the furnaces marked No. 1.

When No. 2 rings

(*a*) Push back and level fires No. 2 (brass numbered) furnace.

(*b*) Co[illegible]es No. 2 (painted number) furnace.

This system will continue through all five furnaces of each boiler in numerical order, thus insuring that each fire will be coaled and pushed back at regular intervals, and it will also give enough bright fire to maintain an even steam pressure and consume the smoke to the greatest possible extent.

At each firing three shovels of coal will be used as a "charge" *no more, no less.* The slicing of the fires will be done at the direction of the water tenders when in their opinion it is deemed necessary. It must be remembered also that too much slicing hinders a man in keeping good fires, and is bad for coal economy.

This system must be strictly carried out when the firing device is in operation, and by its use each man will be required to do his share of work without being told, giving the water tenders more time for other important work and for observations.

Each watch will burn down and clean (when hot) their own fires.

While cleaning fires the firing signals will, of course, be disregarded for that door.

When hoisting or ejecting ashes the signals must also be followed. A short delay in getting ashes out is not to be considered as important as the continuous handling of the fires.

It is essential that *all men* of the fireroom force become familiar with this system at once, and they will be expected to follow it out to the letter.

Where any change in the time of the signals is deemed necessary the chief water tender on watch will report to the engine room the desired time.

When coaling, raking or cleaning fires firemen must work quickly and close the furnace doors promptly.

When cleaning fires in any boiler the draft will be checked by partly closing the damper and putting on ash-pan doors of furnace being cleaned.

When it becomes necessary to check the fires it will be done by the use of dampers and ash-pan doors; never by opening or cracking furnace doors. It may, at times, be advisable to carry dampers partly closed when boilers are steaming easily.

Water tenders will regulate the feed so as to keep the water at from one to three inches from the bottom of the glass, and must determine what valve opening will maintain this level. The practice of opening the valve, allowing the water to rise high in the glass, and then closing the valve is wrong. The feed must be continuous and regular.

All conditions of varying demand for steam, when there are many and frequent changes of speed, cannot be met by any system or rules. In such cases regular firing is not practicable, but whenever abandoned for sufficient cause the system will be taken up again as soon as possible.

One of the principal sources of inefficiency in firing is the leakage of air through boiler casings and a too great opening of furnace doors. Chief water tenders and water tenders must keep a vigilant lookout for leaks around boiler casings and have all possible leaks stopped up.

A too great opening of dampers when steaming easily under natural draft is often a source of waste, since too much air is put into the boiler. The damper should be regulated to suit the rate of combustion.

It must be seen to that dead boilers connected with the steaming smoke pipe are kept shut tight on fire side and that their dampers are securely closed.

ADDITIONAL NOTES ON FIRING.

(See Instructions, Care and Preservation of Boilers.)

107. When using slice bar run it along grates, but do not break up fires.

Do not break up fires with hoe. Only level off and fill air holes.

Remove clinkers as soon as noticed and cover bare spot with live coal.

Keep ash-pit doors on top notch of pawl when open. Don't

put fire tools or anything in ash pans that would prevent doors from closing in an emergency.

Clean fires in one boiler at a time. Pump a little more water in than usual, and close dampers during whole operation. Keep other fires well built up so that steam pressure will not fall.

Keep fires pushed back from furnace doors. There should be no fire on dead plate at any time, nor resting against cheek plates.

Regulate steam pressure by use of dampers in preference to ash-pit doors.

At end of watch leave good round of coal on floor plates for relief.

Blow through all gage glasses and use try cocks once an hour.

Pump firerooms bilge dry each watch. Keep strainers clear.

Blow down and sweep tubes only as directed.

If draft is poor ask officer of the deck to have ventilators trimmed.

Keep accurate tally of coal or oil burnt.

Instructions for Burning Oil Fuel.

These Instructions apply to combination oil and coal-burning boilers using S. & K., Peabody or Bur. S. E. burners.

108. One of the best indications of the proper degree of combustion of oil is, as in the case of coal, the smoke made. Experience has shown the following facts to be proved:

Insufficient air gives a thick, black, oily smoke.

Too much air gives a thick, white, oily smoke.

When the air is just sufficient the smoke is not noticeable.

Experience has further shown that proper mixture of air and oil cannot be obtained by using too large tips. It has been found that the one-mm. tips supplied by the Schutte Koerting Co. burners give about the best atomization, and if an increase in the amount of oil burned is desired the number of burners should be increased, and not the size of the tips.

With the installation on the *Utah,* the following method of burning oil has been found to be the most satisfactory, and the water tenders in charge of firerooms will follow it:

Keep a bed of clinkers over the entire grate, about 8 to 12 inches thick. About the center of the grate keep a ridge of clinkers and ashes high enough for the flames from burners to strike.

Watch the grate carefully and keep all holes in the clinker bed filled up with coal.

Keep all openings in the furnace closed, ash-pan doors, furnace doors, etc., except the opening immediately surrounding the burners. Watch the smoke from time to time. If black and thick, speed up the blowers; if white and thick, slow down the blowers until a sufficient amount of air is being supplied and no more, and no smoke can be seen.

A further check on the proper degree of combustion may be obtained by watching the flames of the burners. If short and white, the combustion is good; if long and yellowish, the combustion is poor. Petty officers in charge of the steaming firerooms are cautioned to keep all these facts in mind and to endeavor to burn oil on their watch as economically as possible.

Any officer attached to the engineer's department who notices excessive smoke when burning oil, if underway, will call the attention of the officer of the watch to it through the quarterdeck tube, and if at anchor, of the machinist mate of the watch, and will ascertain the name of the water tender on watch.

Water tenders and firemen in charge of firerooms must understand that their ability to reduce smoke will be taken into account in making up quarterly marks and recommendations for promotions.

Preparations for Getting Underway in the Firerooms.

109. Before lighting fires examine boiler for water level; open air cock, try cocks and gage-glass cocks and valves. Make certain that valve and pipe leading to pressure gage are open and clear. See that surface and bottom-blow valves are

shut. See that proper firing tools are at hand; shovels, hoes, slice bars, ash-wetting hose, etc.

Find out what bunker coal may be used from, and that it is opened and that coal buckets are handy.

Examine grate bars and brick work; see that dampers are open. If wood or loose paper is available, use for covering grate bars, on top of which spread a layer of coal about 6 inches deep. Orders being received to "light fires," do so, using live coal from other steaming boilers burning coal. Care must be taken until green coal is ignited; then regulate fires with dampers. Steam should form on a Babcock & Wilcox boiler one hour after fires are lighted. If possible, another hour should be used in getting steam pressure up to blowing-off point, 225 pounds.

When steam is formed air and pressure-gage cocks will be closed. Main stop valve opened full and closed one or two spokes of its handwheel.

As steam pressure raises, 20 pounds and upward, all new gaskets and joints will be examined and set up on. Boiler looked over for possible leaks. Try cocks and gage glasses blown through for verification. Loose coal that has fallen through grate bars will be raked out of ash pans, and usually a little sea water is put into ash pit.

As pressure nears blowing-off point safety-valve lifting gear will be tested from F. R. and deck, if circumstances will allow it, by raising valves; F. D. blowers, gotten ready for use, oiled and turned over, gage-glass lamps seen in order. Let steam come up to blowing-off point, note what pressure S. V. lifts, then stop firing, close dampers and check fires.

When connecting, great care must be taken *not to open* the communicating or "feeder" valve quickly. This valve will be slowly unseated, the pressure in boiler and steam line allowed to equalize. This can be done by consulting boiler and line pressure gages. The man handling this valve will always be provided with a wrench, so that feeder valve can be promptly shut, if found necessary to do so. From 3 to 5

minutes should be given to equalizing. The feeder valve can then be opened full, but not jammed open.

Now make certain that check and stop valve are properly regulated to give the feed water required, and that neither of these valves is closed off or blanked; feed pump in working order, and firing may be taken up as per time-firing signal.

Care will also be taken that two or more boilers are not reaching the connecting point at the same time. An interval of from 10 to 20 minutes will be allowed to avoid confusion and possible accident.

All coal placed on floor plates from bunkers will be carefully measured in buckets and a careful record kept of the number of buckets taken from each bunker.

110. The following is a set of instructions in force on a large reciprocating engined vessel fitted for forced lubrication:

ROUTINE FOR GETTING UNDERWAY.

111. Four and one-half hours before engines are to be ready light fires in one extra boiler. (Only to be done if one boiler is in use for auxiliary.)

Three hours before time of getting underway.

(*a*) Steaming watch goes on.

(*b*) Run back boilers to be used, to steaming level.

(*c*) Prime furnaces.

(*d*) Light fires, using fireroom auxiliary boilers.

(*e*) See air cocks and gage cocks open on all boilers to be lighted.

(*f*) See all gage glasses in good condition.

(*g*) Inspect to see that all sighting holes have plates on.

(*h*) Inspect to see that all double bottoms are closed and manhole plates dogged down.

(*i*) Blow out sea chests of main condensers.

Two hours and one-half before time of getting underway:

(*a*) Cut in extra boiler.

(*b*) Open by-pass valves to main steam line.

(*c*) Turn steam on cylinder jackets.

(*d*) Start main air and circulating pumps.

(*e*) Cut exhaust into main condensers.

(*f*) Cut out auxiliary condensers.

(*g*) Shut down evaporators.

Two hours before time of getting underway:

(*a*) Test out water service.

(*b*) Warm up and test out extra main feed pump.

(*c*) Warm up and oil service pump in each engine room and test out oil service.

(*d*) Start extra hotwell pump.

(*e*) Warm up one auxiliary feed pump.

One and one-half hours before time of getting underway:

(*a*) Have machinist's mate stand by steering engine.

(*b*) See exhaust open and turn steam on steering engine.

(*c*) Lift safety valves of boilers by hand.

One hour before time of getting underway:

(*a*) Test out gages cocks in all boilers.

(*b*) See exhaust valves on anchor-engine line open.

(*c*) Have man on watch in evaporator room stand by to start four evaporators.

When steam pressure in main steam line has risen to point where main and auxiliary are equalized:

Open feeder valves in steaming firerooms and close by-pass.

As pressure in boilers newly lighted rises:

(*a*) Inspect bottom blows and see that they are tight.

(*b*) Regulate by use of dampers and ash-pit doors so that pressure in boilers comes up one at a time.

(*c*) Allow each boiler to lift safely by steam.

(*d*) Set safety valves at authorized pressure.

(*e*) Cut in boilers, one at a time, cracking boiler stop until pressure has equalized between boiler and main steam line, then open stop wide.

Three-quarters of an hour before time of getting underway:

(*a*) See that all engine-room annunciators, telegraphs, voice tubes and bells are O. K. Call up officer of the deck and have them tested from the bridge.

(*b*) Find out from the officer of the deck boats to be hoisted in and prepare to correct list.

(*c*) Set links at full gear.

One-half hour before time of getting underway:

(*a*) Get permission from the officer of the deck to try out main engines.

(*b*) Start oil pumps.

(*c*) Try out main engines.

(*d*) See pressure on fire main.

As soon as all boilers are cut in:

(*a*) Start extra main feed pump.

(*b*) Start other feed heater.

(*c*) Start four evaporators.

(*d*) Report ready to senior engineer officer.

(*e*) Report ready to the officer of the deck.

While warming up main engines see that cylinder drains are open at all times and frequently move your valves by use of the reversing lever.

The evaporators should be started as soon as four boilers are cut in on the main steam line and three boilers on the auxiliary line.

ROUTINE FOR COMING TO ANCHOR.

112. Two hours before time of anchoring:

(*a*) Deck should notify the officer of the watch.

(*b*) Clean ash pits and eject all ashes.

(*c*) Find out what boilers are to be used for auxiliary.

One-half hour before time of anchoring:

(*a*) See that exhaust to anchor engine is open.

(*b*) Turn steam on anchor engine.

(*c*) Start pump on fire main.

(*d*) Take extra feed to bring level in tanks above center of upper glass.

(*e*) Run links out to full gear.

(*f*) Shut off L.P. rod packing.

(*g*) Swab all rods with vaseline.

(*h*) Find out which engine-room auxiliaries are to be kept.

(*i*) Notify dynamo room to have sufficient generators running for power on cranes.

(*j*) Burn down fires in boilers to be cut out, taking care that full pressure of steam is kept.

Fifteen minutes before time of anchoring:

(*a*) Notify engineer officer.

(*b*) Have men detailed to stand by annunciators and cylinder drains.

(*c*) Have men stand by evaporators.

When anchored:

(*a*) Notify firerooms that anchor has been let go.

(*b*) Start four evaporators.

When word has come to secure:

(*a*) Shut down oil pumps.

(*b*) Shut down water service.

(*c*) Let fire die down in boilers to be cut out.

(*d*) Transfer all coal on floor plates to fireroom containing auxiliary boilers.

(*e*) Start auxiliary air and circulating pump of auxiliary condenser to be used.

(*f*) Slow down main feed pump.

When fires in boilers have burned down enough to handle:

(*a*) Fill boilers to within an inch of top of glasses.

(*b*) Close feeder valves to main steam line.

(*c*) Relieve pressure on main steam line by by-passing steam line and separator traps.

(*d*) Watch main steam gage. The pressure will rise, but if it does not exceed five pounds in five minutes after draining line, shut down main condensers and start auxiliary condensers. If pressure rises, set up tighter on feeder valves.

(*e*) Shut down spare main feed pump, spare hotwell pump and spare feed heater.

(*f*) When fires have died down in boilers to such an extent that steam can be held, cut out these boilers. Leave ash-pit doors on and close up boilers. Fires are never to be hauled till dead, except in case of accident.

(*g*) Bank fire well up against leg nipples.

(*h*) Clean up engine and firerooms and put away tools and firing implements.

(*i*) Dismiss steaming watch and set auxiliary watch.

XXIII.—CARE AND OPERATION.

Routine Orders for Engine-Room, in Port.

113. Be careful to secure pumps, air compressors, etc., when they are no longer needed.

Clean engine-room bilges each week on day assigned.

Allow no one in engine rooms or firerooms from 9:00 P. M. to 5:00 A. M. except men on watch and those on duty.

No smoking in engine-room hatches. Men will be kept out of hatches except those detailed there for cleaning stations.

Keep all unnecessary lights turned out at night.

In general, run evaporators on ship's tanks from 8:00 A. M. until they are full, then shift below to reserve-feed tanks for the night. This will avoid overflowing ship's tanks during the night.

Jack daily auxiliaries not in use.

The oiler on watch should always know who are the officer and chief petty officers on duty. Their names should be entered on the auxiliary watch list or condition blank kept at engine-room-log desk.

In case of any accident or derangement the officer and chief petty officers on duty will be informed.

Special Orders for Operation Machinery, Engine Room.

General.

114. The vacuum will be kept as high as possible in main condenser, but not by undue speeding up of main air pump. Run circulating pump so as to have about 100 degrees F. overboard discharge.

Great care will be taken against mixture of salt water with the oil service at such places as the thrust bearing. A careful watch will be kept against loss of oil, particularly at the thrusts.

Clean bilge and oil strainers every watch.

Keep 5–15 pounds (special direction on each vessel) back pressure on auxiliary exhaust line. If line fills with water, use drains or lower back pressure occasionally to clear line of

water. Every effort will be made to keep feed temperature as high as possible.

Keep about 5–10 pounds oil pressure on bearings fitted with forced lubrication. A somewhat higher pressure may be necessary at pumps or in oil lines, but a high oil pressure is conducive to waste of oil.

Turbines.

115. Have all throttles, especially backing throttles, warmed up when coming to anchor.

Take clearances regularly, and especially after a combination of turbines has been changed.

Keep careful watch on thrust bearings whenever a change of speed or shift of combination is likely to cause considerable load on thrust.

Keep gland steam carefully adjusted so as to avoid excessive leaks of steam into engine room and air leaks into turbines.

Reciprocating Engines.

116. Do not swab piston rods except when ordered and in accordance with special directions.

Run cut-offs out full before getting underway or coming to anchor.

Test reversing gear before anchoring.

Engine-Room Aids.—On Watch.

117. The officer on watch is usually at the desk in the starboard engine room, and near by should be found the following aids:

Port and sea routine (preferably in a bulletin board).

Book of routine orders.

Morning order book (contains for the night and following morning orders additional to the routine and routine orders).

Muster lists of steaming sections, auxiliary watch, etc.

Tables of water in double bottoms, per inch, as sounded.

Condition blank, showing what machinery is in operation, etc.

Booklet of skeleton pipe plans (in the desk).

Table showing heaters and pantries on each heating circuit.

Counters, tachometers, revolution indicators, clinometers, rudder indicator and time-firing device are installed near operating station.

118. *Steaming Data Table.*—This consists of a table giving speeds, corresponding revolutions for full, standard, ⅔ and ⅓ speed, pressures and valve setting or turbine combination; fuel required and boiler power required. Other data may also be added, such as air pressures, time-firing intervals, feed pumps required, etc. This will be useful in determining immediately what changes are needed for modifications in speed and avoids confusion and inaccuracy on this point. A copy of this table should be on the bridge for the information of the officer of the deck.

A copy of speed and corresponding revolutions is sometimes placed on a cylinder in a case with arrangements for turning it, so that the particular speed required can be turned to the opening.

It is also found useful to have a clip upon which is placed a slip of paper upon which appear the standard speed and revolutions called for.

Boiler Room.

119. Run auxiliaries at least once a week by steam.

Clean fireroom bilges every week on day assigned.

Obtain permission from officer of the deck to blow tubes or eject ashes.

Keep unnecessary lights turned out.

Keep bilges pumped dry.

Keep fireroom floor plates cleared up.

Allow no one in firerooms from 9:00 P. M. to 5:00 A. M., except men on watch or duty.

Chief water tender on day's duty inform officer on duty whenever a bunker runs empty and get instructions about bunker to be opened.

Chief water tender on day's duty will inform officer on duty and officer in charge of station (or chief petty officer of substation) whenever any derangement occurs to machinery or boilers.

Work in Dry Dock.

120. While in dry dock, all openings in hull below water line to be closed at end of working hours.

All sea valves will be removed, examined and ground in if necessary.

Sea chests will be examined for corrosion, and cleaned out.

Bolts and rivets securing sea chests to be carefully examined for corrosion and should be tapped with hammer to see if they have become brittle.

Strainers to be cleaned and bolts and nuts securing them to be carefully inspected.

Valve stems to be inspected for corrosion and condition of thread noted. Any stems in bad condition to be renewed.

Zincs to be examined and renewed if necessary.

Stuffing boxes to be repacked.

All bolts, nuts and joints of sea chests and valve chests to be carefully inspected.

Before entering dock have spare zincs ready.

Make out a detail for work in dock on the following lines:

Each station will take care of its own valves and other work. Extra machinists on auxiliary station will be assigned to engine room.

Select good men for helpers for each machinist.

Detail men for any other special work, such as cleaning propellers.

When flooding dock have necessary floor plates up so that all valves may easily be seen.

Have a petty officer standing by each valve, who is to report any leak discovered.

The warrant officers will inspect the valves they overhauled while dock is being flooded.

1. *Stern-Tube Stuffing Boxes.*—Packing to be inspected and renewed if necessary.

2. *Propellers.*—Inspect blades to see if bent or injured in any way.

Smooth blades as much as possible.

Examine studs and nuts securing blades to hub.

Examine nut on end of shaft.

Measure amount shaft is down.

Remove plug from coupling casing and see that casing is filled with tallow.

In time before docking see that there are a sufficient number of spare zincs on hand.

Keep a record of work to be done in dock.

When in dock make a note of work which will probably be necessary at next docking.

Information for Officer of Deck and Ship's Officers.

121. A great deal of confusion and difficulty in connection with keeping station, being ready to change speed, etc., can be avoided by a proper coöperation between the officer of the deck and engineer officer on duty.

The presence of the *Steaming Data Table* on the bridge, and other general information such as the following, will assist matters generally.

This matter should be prepared as far as possible when a vessel is commissioned, and then whenever any point comes up decision and rule should be made to cover it. In this way in a short time a set of valuable rules and decisions are obtained with which all concerned are familiar and which make for system, uniformity and despatch.

The following are some matters treated of:

122. As there has been considerable difficulty in having messages from bridge to engine room understood, and messages more or less confusing are sometimes received in the engine room, the following points tending to eliminate confusion may be mentioned:

Messages should be as short and distinct as possible, spoken clearly and distinctly into tube, and should be repeated back.

There is considerable noise in the engine room, and unless messages are given distinctly they cannot be well understood.

The engineer officer of the watch is not always at the tube, and on occasions it may take as much as a minute to get him.

There is, however, a man at each throttle, and any orders for change of speed, etc., will be immediately carried out as soon as message is understood in engine room. Calling specially for officer of the watch may often delay the execution of an order.

When *change of revolutions* is desired, the number should be indicated on the revolution indicator. This will be a check on any message sent by voice tube and is understood immediately.

It requires an appreciable time, at least a couple of minutes, after a change in speed to tell accurately what revolutions are being made. They have to be counted. The tachometers, which are also on the bridge, give the approximate revolutions, but are not always accurate. The exact revolutions cannot be made till after careful adjustment. So that when a call for change of revolutions is made one immediately after another, the revolutions made have to be guessed at, and an inquiry as to what revolutions are being made under such conditions can not receive an accurate answer. The approximate number can be told from the tachometers on the bridge.

In *starting* out from dead in the water, especially on getting underway, it requires several minutes to enable the engines to speed up to the revolutions desired. It will require, roughly, 3 minutes to get up to 12 knots, and 5 or 6 to get up to 15 knots. In the meantime, although the belt pressure may be in the turbines, the revolutions will not be secured till the inertia of the ship and the rotors has been overcome.

Constant revolutions cannot be maintained when the helm is put over, although the changes of heading may be small.

Large variations in revolutions cannot be made with certainty without several minutes' warning. The warning desired is a statement of the revolutions that will be required and duration of change. Orders to have plenty of steam, to

start blowers, or to shift combinations, are of little assistance, as they do not tell what is required.

Warning of any *slowing down* should always be given, and if possible the duration of the slowing. Informing the engine room when the anchor is let go, or to be let go, is particularly desired and will save trouble and also considerable fuel.

Orders to change the *standard speed* will be transmitted to the engine room by voice tubes and, unless otherwise directed, the signal of execution will be a ring of standard speed on the engine-room telegraph.

When engine-room telegraph rings standard speed after having been on any other speed, the speed of the engines will be taken from the reading of the revolution indicator; accordingly the officer of the deck should see that the revolution indicator is properly set.

XXIV.—CONDUCT OF BUSINESS IN ENGINEER DEPARTMENT.

123. A definite setting forth of time and place for carrying on routine matters similar to the following will be of great assistance.

In order to ensure prompt dispatch of business in the engineer department the following will be done:

The engineer officer will be at the office from 8 A. M. to 8:45 A. M. and from 11:30 A. M. to noon.

From 8:45 until time for quarters he will be about the department. He will also be about the office between 1 P. M. and 2 P. M.

Officers having matters to bring up should do this at the office during the period of 8:00 to 8:45 as far as possible, this being a general consultation period.

Matters requiring the attention of the engineer officer but not necessitating immediate action should be placed in his receiving basket, when it will be attended to on his next visit to the office.

This should include any message, since he may return to the desk before being found by the messenger.

The period 11:30 to noon is a period set aside for men's requests, personal business, investigation of reports, etc.

124. The *officer having the day's duty* will be in the engine room or in the immediate vicinity from forenoon turn-to until 9:30, so that memorandum orders, stub requisitions, etc., can be supplied without delay and that information and directions about any of the work may be immediately available.

They will also be in engine room from 1 to 1:30 P. M. for same purpose.

125. The *officers in charge of stations* are expected to be on their stations where their presence is most needed during working hours.

The headquarters for the auxiliary station will be the machine shop. The officer on the auxiliary station will keep the machine shop informed of his whereabouts so that an inquiry at the machine shop may readily locate him.

Memo. messages for warrant officers of stations may be left at:

Water tender of steaming fireroom; for boiler-room station.

Oiler on watch; for engine-room station.

At machine shop; for auxiliary station.

Name of officer having the day's duty will be written on the auxiliary watch list in the engine room and changed whenever he is relieved.

Names of officers and chief petty officers on duty will be kept posted in engineer's office.

126. Information as to what liberty and drills will be given will be sent to the officer on duty. When this information is not received it should be requested for. This information is to be kept on hand at the starboard engine-room desk, marked on a condition blank or on file, and will be published throughout the department, via voice tubes, as soon as received. When no word is passed it will be understood that the regular routine will be followed.

XXV.—GENERAL INFORMATION FOR ENGINEER FORCE.

127. *Messes.*—The captain of the mess, a petty officer, 1st class, is in charge of the mess and is responsible for order and proper conduct of all men of the mess, also for the detail of mess striker and temporary relief when necessary. His authority cannot be questioned, and he has full authority to give orders and directions to the messmen in regard to cleanliness and manner of serving food. Complaints concerning food should come through the captain of the mess.

128. *Sleeping on Billets.*—Men must sleep on their proper authorized billets so that they can be called at night without trouble. Men who do not sleep on their billets will be responsible for being present when they are required, and the excuse that messenger did not call them will not be considered.

129. *Quarters and Drills.*—Men must be on the alert and come to quarters promptly when calls are sounded.

At regular morning quarters all men not on watch, and not at work, will come.

At quarters for coming to anchor and getting underway, engineer's force is not required to fall in. But all men who wish to stay on upper decks must fall in ranks and remain there until retreat.

At all calls for general drills, general quarters, fire quarters, collision, engineer's force will proceed to their stations unless some word to the contrary has been received.

130. *Morning Quarters in Port.*—The following men of the engineer division will come to morning quarters in port:

Messmen.

Auxiliary watch.

Dynamo, evaporator and ice-machine men who had the 4 A. M. to 8 A. M. watch.

Steamer crew that has liberty day.

Washroom keepers will stand by their washrooms.

These men will be mustered by the water tender of the auxiliary watch.

At sea, sections not on watch and all men not turning-to on their stations will muster at quarters.

Officers of stations desiring to have special men excused from quarters will submit lists to engineer yeoman before quarters.

On Saturdays and Sundays all men not on watch or excused for work will come to quarters.

131. *Bearing and Behavior.*—Although the engineer division is excused from most of the military drill, its members should bear in mind that they belong to a *military organization* and should always maintain a proper military bearing and behavior.

Men must not appear on deck dirty, without head gear, or out of uniform. When not at work men should appear neat and clean, and it is generally observed that those who are neatest and cleanest after work is finished have usually done the most work, while those who appear slovenly at muster usually do their work in a slipshod manner.

132. *Petty Officers.*—Chief petty officers are in charge of all the various sub-stations, and their authority on their station and over their subordinates is as complete and thorough as is that of the officers. The authority of all petty officers must be thoroughly respected by all men placed under them, and in all cases, either on or off duty, proper deference must be accorded to petty officers by all subordinates.

133. *Section Officers.*—Men should look to their section officers for advice on personal matters, matters of conduct, study for promotion, etc.

134. *Work and Working Periods.*—Regular working hours are ordinarily adhered to, and the average working period is about 42 hours per week; but work outside of the regular hours may be ordered at any time when necessary. Men on any station must keep that station in running order, and when necessary overtime and night work will be done.

The standing of a watch, or watch for a part of a day, does not necessarily excuse a man from work on his station should his services be required.

135. *Relieving Promptly.*—Nothing is probably more important for the orderly carrying on of work than a prompt relief at the end of a watch and a prompt turn-to at the beginning of a working period. If a man is late not only does he lose time himself, but he causes others to wait for him, and generally upsets things, delays work, and disturbs the work of others.

Cleanliness and Order.

136. *Shoe Bags.*—It is recommended that men provide themselves with shoe bags so that shoes may be stowed away without dirtying clean clothes.

137. *Dirtying Up Paint Work.*—Men should be careful about this. When men are at dirty work and have to go to the head or place that requires passing through living spaces, they should clean their shoes or shift their shoes and brush off their clothes, so that the effect of dirtying decks and paint work is as little as possible.

138. *Clothes in Engine Rooms and Firerooms.*—Ship's orders about these clothes must be complied with. This is a privilege allowed to the men for their convenience, and must not be abused. Clothes in engine room must be down by 9:00 A. M., and must not be placed where they interfere with any of the machinery. Clothes lines will not be rigged in engine or firerooms except as specially authorized.

Miscellaneous.

139. Fireroom force will not be allowed to use engine-room ladders to go to and from firerooms.

Whenever the engineer's force is dismissed during drills or quarters they must keep out of the way and clear of all divisions drilling.

Fire tools and coal and ash buckets not needed in port should be stowed away upon arrival in port.

All buckets, wrenches, portable lights, etc., must be kept in their place when not in use.

No loitering is allowed in engine-room hatches and no clothes are to be hung there.

On Sundays and holidays the department must be kept ready for inspection.

The petty officer on duty will be instructed to make frequent inspections of firerooms outside of working hours to see that there is no gambling or drinking going on.

Scrubbing clothes or bathing will not be allowed in engine or firerooms.

No bedding or caulking mats will be allowed below.

All bilges must be kept as dry as possible in port. The machinist on watch will inspect all bilges every watch and have them pumped dry.

No water except for testing purposes is to be drawn from idle boilers.

No iron, pieces of broken tools, buckets, shovels or stores of any kind are to be thrown overboard without authority from the engineer officer.

Wrenches must not be used for opening valves unless it is necessary, and if necessary a note of the fact will be made in the repair book. Valves should be closed by hand firmly, not jammed; if they are jammed or set up with a wrench, leaky valves are sure to result. Valves should never be opened all the way and allowed to stay jammed open. Turn back half a turn, until free. Wrenches must not be used for hammers. If a hammer is required, send for it, or have it with your tools when you are going to need it.

Waste used on ice machine, evaporator, in the engine-room and fireroom stations will not be thrown away, but will be kept in a bucket on the various stations. At 10:00 A. M. daily, the storeroom keeper will be sent around to collect all this waste, and will clean it in the waste-cleaning machine and dry it and turn it in to the storeroom.

Any one wishing to use instruments, books or drawings belonging to the department will draw them through the office and sign a receipt for them.

Men of the engineer's force are not permitted to go to engineer officer's room. Any man desiring to see the engineer officer will go to the office at the time assigned. In emergen-

cies outside of regular time the yeoman or messenger will report the name of the man and the reason for wishing to see the engineer officer.

XXVI.—GENERAL INFORMATION FOR OFFICER OF DECK AND SHIP'S OFFICERS.

(Applies to late Capital Vessels.)

140. Information as to time for preparation and notice concerning getting underway.

Time to get ready to get underway, auxiliary boilers in use other boilers not primed, but ready, 3 hours.

Time to get ready to get underway, auxiliary boilers in use, other boilers primed, 2 hours at least.

Time to get ready to get underway, from banked fires, engines secured, at least 2 hours.

If engines have been secured within a few hours this time may in emergency be reduced to 1 hour, depending on circumstances. This cannot be depended upon.

Time to get ready to get underway, banked fires, engines standing by, not secured, about 10 minutes.

Full speed, however, cannot be given till there has been time to spread the fires properly.

When an order has been given to be ready at a certain time, this time of being ready cannot be materially hastened unless word is received 2 hours before the time set.

When an order is given to be prepared to get underway on a certain time of notice, the department will not ordinarily be prepared to be ready at a shorter notice than that given.

The time required in preparation is largely based on what period is necessary to properly warm up and test parts of the machinery. Attempts to hasten this time may lead to improper warming and consequent damage, and while in real emergencies some risk of this kind may be taken, it is considered bad practice to attempt to hurry time of preparation

beyond times given above, though it may be actually possible to get underway sooner by taking risks.

Full speed, above 12 knots, cannot be depended on immediately on getting underway, especially when boilers have been banked and getting underway, has been delayed for some time. Holding back fires detracts from their steaming capacity, and it requires some time to put them in good shape again.

Speed above 12 knots cannot be immediately obtained from dead in the water, and it requires 5 minutes or more ordinarily to work up to 15 or 16 knots. If a slow speed is run first, giving a chance for the machinery to get warmed up, the high speed can then be more readily obtained. With reciprocating engines maneuvering is more certain and changes in revolutions affect the vessel more distinctly. Movements have to be anticipated more with turbines than with reciprocating engines, and the backing effect is more limited.

DISCUSSION.

THE DESIRABILITY OF USING HIGH MEAN REFERRED PRESSURES.

EDWARD M. BRAGG, S. B.—In the February, 1913, number of the JOURNAL I had an article of the above title. In the May, 1914, number of the JOURNAL Lieutenant Commander Dinger took exception to certain statements made in that article. His objections come under two heads; he objects to placing so much stress upon the question of mean referred pressure, and he objects to my statement that a high mean referred pressure can be used with economy even if the expansions have to be reduced in order to produce it.

Lieutenant Commander Dinger implies that it is quite unorthodox to put so much emphasis upon mean referred pressure, that the emphasis should rather be upon expansions and high card factors. He objects to emphasizing mean referred pressure because it "is a result, not a premise"; because it "is an incident and a consequence and is not a basis." The statement that mean referred pressure is an "incident" I cannot agree to, but I quite agree that it is a "result" and a "consequence." It is for this very reason that it can be used to advantage as a basis for plotting experimental results.

In the article of February, 1913, I referred to a paper read by Mr. Royds in which he gives the results of numerous experiments upon engines, and as a result of these experiments the following table was given:

TABLE I.

.....	Single-cylinder, 75 pounds absolute.	Multiple-expansion, 165 pounds absolute.	Multiple-expansion, 200 pounds absolute.	Multiple-expansion, 250 pounds absolute.
Unjacketed, non-condensi'g	37	42–47	48–53	53–58
condensing.....	35	40–45	45–50	50–55
acketed, condensing.....	33	38–43	42–47	47–52
Superheated slightly.....	32	36–41	40–45	45–50
highly.....	30	33–38	37–42	42–47

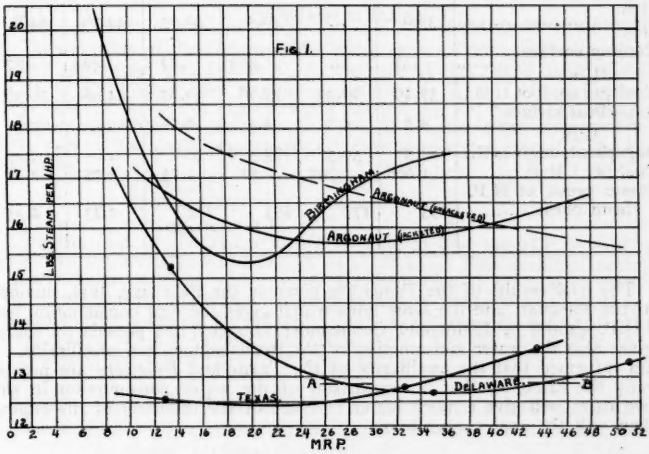
It can be seen from this table that it was fully recognized that the best mean referred pressure would vary with the initial pressure, back pressure, degree of superheat, etc.

In my opinion one is less apt to fall into error by using mean referred pressure as a basis of design than by using number of expansions.

Lieutenant Commander Dinger fears that by reason of placing much emphasis upon the mean referred pressure some may be tempted to get a high value by admitting live steam to the intermediate and low-pressure receivers. One would fall into the same error if high card factors are emphasized. The card factor is a purely arbitrary quantity. For convenience of design a certain theoretical expansion curve is assumed ($p\ v = \text{const.}$), and the card factor simply expresses the degree to which the actual

expansion curve approaches the assumed. The card factor is merely the ratio between the actual mean referred pressure and the mean effective pressure of this theoretical diagram. The actual expansion curve can be made to approach and even cross the theoretical curve by admitting live steam to the receivers. The person who would make this mistake under one system of design would make it under the other.

When the steam consumption is plotted upon the mean referred pressure as a base it will usually be found that the curve will have the character shown in Fig. 1. The economy at A and B are the same for the *Delaware*, and by using the mean referred pressure at B a smaller, lighter engine will be obtained, and when all things are considered it will be a more economical engine than if the smaller mean referred pressure had been used.



My statements in regard to the desirability of using a smaller number of expansions than has been customary were based upon numerous experiments given in the paper by Mr. Royds. In these experiments the steam consumption of the engine alone was obtained. Lieutenant Commander Dinger's objections to my statements are based upon the coal-consumption tests of the propelling machinery of certain vessels of the Navy. The coal consumption is a function of the efficiencies of the boilers, engines, piping, auxiliaries, fireroom force, etc. He practically asks us to assume that in all these tests the efficiencies of everything except the engines were the same; and that it was a variation in the efficiency of the engines alone which caused the difference in coal consumption.

A glance at some of the proportions of the propelling plants will show that it is extremely unlikely that the coal consumption was a function of the engine design alone. The rate of combustion per square foot of grate surface affects the efficiency of the boilers very materially, as shown by tests upon the boilers of the scout cruisers. (See plate 14, opp. page 830, Aug. 1910, JOURNAL.)

The coal-consumption test of a plant as a whole cannot be taken as a criterion of the performance of one piece of apparatus in that plant. The coal consumption will be affected very largely by the skill of the firemen,

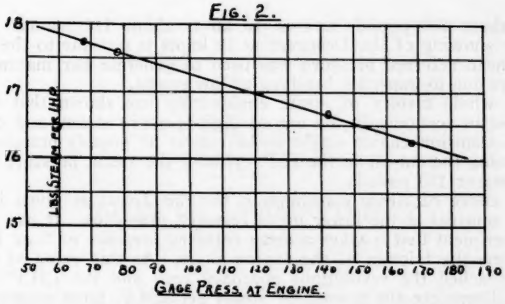
leakage of boilers and pipe lines, use of exhaust steam in feed heaters, etc. The economy of the engines can only be determined by steam-consumption tests. The table of best mean referred pressures which I have given is based upon steam-consumption tests of engines, while the evidence that Lieutenant Commander Dinger offers to the contrary is based upon coal consumption, and is not conclusive.

.....	*Delaware.*		*Michigan.*	*Texas.*	*North Carolina.*	*Birmingham.*
	21 k.	19 k.				
I.H.P / G.S.	20.59	12.05	15.76	18.16	17.15	22.83
H.S. / G.S.	38.6	...	40.5	40.03	42.76	54.6
Cooling surface / H.S.	.38	...	.402	.42	.424	.57
Coal per sq. foot G.S.	37.49	20.92	23.28	36.85	44.96	50.38
Superheat surface / G.S.	4.3	4.5	4.5	2.1	...	...
Superheat, degrees F.	61.5	50.5	85.5	40	...	...
Coal per I.H.P.	1.888	1.795	1.51	1.73	2.75	2.28
Steam press. at H.P. steam chest	253	177	253	274 at engine.	2.43	2.25

The trial results of the *Texas* are given in the February, 1914, number of the JOURNAL, and the same table which gives the coal consumption per I.H.P. quoted by Lieutenant Commander Dinger (1.73 pounds of coal), gives also the water consumption of the main engines and auxiliaries. I am informed that the auxiliaries of the *Texas* and *Delaware* are practically the same, so that a comparison of the water consumption in the two cases will give a much better measure of the economy of the engine than will the coal consumption.

.....	*Delaware.*			*Texas.*		
Speed in knots	21.56	19.217	12.24	21.05	19.078	12.137
I.H.P. main engines	28,578	16,602	3,905	28,373	18,779	4,640
auxiliaries	934	733	341	1,025	805	430
Steam pressure: H.P. steam chest (gage)	253	177.4	67.6	.....	.....	.....
1st. rec. (abs.)	107.5	83.1	35.3	91.2	73.3	32.2
M.R.P.	51	35	13.3	43.6	32.6	12.8
H.P. cut-off	.86	.86	.86	.785	.605	.54
Total steam consumption, lbs. per hr.	422,931	243,810	83,463	427,182	271,727	80,579
(1) per I.H.P. main engines	13.38	12.7	15.12	.....	.....	.....
(2) per I.H.P. all machinery	14.32	13.91	19.37	14.53	13.87	15.89
(1) / (2)	.932	.912	.78	.....	.....	.....

FIG. 2.



In the trials of the *Delaware* the water rates of the engines and auxiliaries separately were obtained. In the case of the *Texas* only the water rate of the engines and auxiliaries together is given. If we assume in the case of the *Texas* that at equal powers the water rate for the main engines alone bears to the water rate for all machinery the same ratio as in the case of the *Delaware*, we get the following water rates for the three speeds:

21.05 knots	19.078	12.137
13.57 pounds	12.78	12.56

In the case of the *Texas* it will be noticed that the H.P. cut-off was reduced to .605 at 19 knots and to .54 at 12 knots, thus enabling the lower power to be obtained with greater economy than if the steam had been throttled down. The value of using as high a pressure as possible in an engine when running at reduced power was shown in the tests of the *Argonaut's engines* (Trans. Inst. Nav. Arch., Vol. 14, 1889). In one of these tests the following results were obtained:

H.M.S. "ARGONAUT" STARBOARD ENGINE, MAX. POWER 9,390 I.H.P.

R.P.M.	Press. at Eng. Gage.	Total expansions.	I.H.P.	M.R.P.	Vac. Ins.	Lbs. of steam per I.H.P.
74.7	168	16.1	1907	16.4	25.5	16.26
75.	142	13.5	1922	16.4	25.5	16.68
76.7	78	9.3	1929	16.1	26.1	17.58
76.0	68	8.5	1931	16.3	26.2	17.72

It will be seen in this test that the I.H.P., R.P.M., M.R.P. and vacuum were practically constant. The cut-off of the H.P. cylinder was decreased and the initial pressure at the engine was increased sufficiently to keep the power constant. The steam consumption is plotted in Fig. 2 upon initial pressure at the engine, and it can be readily seen how important it is to keep the initial pressure at the engine as high as possible when running at reduced power. In the case of the *Delaware* at 12 knots the pressure in the H.P. steam chest was 67.6 pounds, and the undesirability of using such a low pressure in a triple-expansion engine is shown by the increase in the steam consumption. In the case of the *Texas* the initial pressures are not given, but, judging from the pressures in the first receiver, it would appear that at 19 knots the pressure must have

been about 230 pounds and at 12 knots about 115 pounds gage. The poorer showing of the *Delaware* at 12 knots is not due to the fact that a high mean referred pressure was used to generate her maximum power, but was due to improper handling at low power.

The whole history of steam engineering has shown that there is an increase in economy in the use of high-pressure steam, and certainly no triple-expansion engine ought to be run at 67 pounds pressure when by shortening the cut-off in the H.P. cylinder the steam pressure might have been nearer 150 pounds.

The curve of steam consumption for the *Texas* as given in Fig. 2 is rather unusual at the lower mean referred pressures. It has been found by experiment that it takes a mean referred pressure of 3 or 4 pounds to overcome the friction of the engine alone. As this value of the M.R.P. is approached the revolutions approach zero and the I.H.P. approaches zero. Therefore the pounds of steam per I.H.P. must approach an infinite value. The curves of the *Delaware, Birmingham* and *Argonaut* exhibit this tendency very clearly, but the curve for the *Texas* shows it but slightly.

The steam-consumption tests show that the smaller engines of the *Delaware* were a trifle more economical than the larger engines of the *Texas* at full power. The better economy of the *Texas* at reduced power was due to the operation and not to the design of the engines.

COMMENT ON DISCUSSION.

LIEUTENANT COMMANDER, H. C. DINGER.—The objection made by Mr. Bragg that my data was based on coal consumption and not on water consumption does not in any way vitiate the comparison. As was stated before, the boilers are of the same design, and under the conditions under which they operate their efficiency will not vary by any much greater amount than does the water consumption of engines built on the same design. The reason that coal consumption and not water consumption was used is that it is only on the recent vessels that water consumption was measured. Where water consumption has been measured the comparisons, all things considered, show in general the same thing as the coal consumption comparisons, namely, that the high cylinder ratio used in late U. S. naval engines results in better economy.

The cylinder ratio in the case of the *Delaware* and *Texas* is not very materially different, and on the whole, from the trials, the engines of the *Texas* appear to be more economical at all speed except maximum. The extra water consumption of the *Texas* on full-speed trial may be accounted for by an extra consumption of the auxiliaries. On the *New York*, a sister vessel to the *Texas*, the auxiliaries use considerably more water than on the *Texas*.

The matter of operation, as Mr. Bragg states, has a great deal to do with the economy shown on tests, but when engines having the high cylinder ratio consistently year after year show a better economy it does indicate that the high cylinder ratio probably is a good thing as far as securing economy is concerned.—H. C. D.

NOTES.

NOTES ON AERONAUTICS.

Extracts from Various Sources.

AIRCRAFT IN WARFARE: THE DAWN OF THE FOURTH ARM.—No. I.

By Frederick William Lanchester, M. Inst. C. E.

INTRODUCTION.

All authorities may today be said to agree on the broad fact of the utility and importance of the flying machine or aeroplane—or, more broadly, aircraft—in warfare; but at present the air service as a fourth arm of the military organization, either of this country or of any of the other great military Powers, can only be regarded as of a tentative and experimental character.

It is, unfortunately, not yet possible to draw conclusions of lasting nature from the actual usage of aircraft in the present war, mainly for two reasons: Firstly, the machines at present available (with possibly a few exceptions) are entirely without armor or defence of any kind and, dirigibles apart, are, generally speaking, without guns or other offensive armament of an effective character. Secondly, the machines are numerically so weak that, as an arm of the Service, the aeronautical forces are a negligible factor. The question of sufficiency in numbers is evidently dependent upon the point of view taken. On the one hand, if we regard the flying corps as merely the successor to the pre-existing balloon corps, the numbers, as they at present stand, may be regarded as sufficient; indeed, perhaps, even liberal. On the other hand, if we would recognize in the advent of the aeroplane the dawn of a fourth arm (this being the point of view adopted in the present series of articles), the present numbers, which in no case represent one-twentieth part of 1 per cent. of the total forces, are a truly negligible quantity. In order to get a fair perspective of the position from the present standpoint, it is sufficient to institute a comparison with the cavalry, to which arm, from its function, the aeronautical arm is most closely akin. Here the accepted numerical proportion in a modern army is about 6 per cent. of the total of all arms. Now there are many otherwise competent authorities who would deny to the aeroplane (or to aircraft generally) the potential importance which the writer hopes satisfactorily to demonstrate is its due; let us put the matter to the test. We hear constant reports of the work done by German aircraft, and particularly the effective tactical reconnaissance of the German aeroplanes, which appear to be continuously employed during the course of every engagement for locating our gun positions, directing gun fire, following up bodies of troops in retreat, &c. We also hear reports of their wider field of operations, presumably carrying out reconnaissance of the strategic distribution of the forces of the Allies at points remote from the enemy's lines. We may presume that the Belgian, French and British aircraft are employed with equal success; but here, in the nature of things, the information that appears in our own Press is meager. As already pointed out, the total number of machines engaged is microscopic; the Germans are

reputed to have possessed at the outbreak of hostilities some 500 machines in all. If the German cavalry had been limited to 500 mounted men, would they have been ever heard of at all? Answer is unnecessary. It may be reasonably argued that the capital value of an aeroplane, with pilot and observer, being so much greater than that of a cavalryman, the above comparison is unfair; granting this objection, we may perhaps admit that the cost equivalent of 500 aeroplanes would be ten squadrons of cavalry, say 1500. This does not seriously alter the position; such a force would be quite unperceived and be of no tangible service to the German army of today.

If, then, instead of the present moment being that of the introduction of the aeroplane (and dirigible), it had chanced to be the moment when mounted men were put on trial for the first time as a fighting machine, and presuming the initial trial to have been made on a similarly modest scale, the mounted men would, relatively speaking, have proved a failure, and no one, not possessed of exceptional intuition of foresight, would have had the least conception of the possibilities of cavalry when numerically sufficient, and handled in sufficient masses and with appropriate supports.

The foregoing is not put forward as a rigid demonstration that the air service is in the future destined to become as important an auxiliary to an army in the field as the cavalry of today; it is no more than an illustration illuminating the view the present writer (in common with some few others) holds, but which clearly is not yet the official view, in this country at least. The great difficulty in connection with the present subject is that in order to get the future into true perspective, it is necessary to be able to look forward along two parallel lines of development—*i.e.*, to visualize the improvements of aircraft possible in the near future as a matter of engineering development, and simultaneously to form a live conception of what these improvements and evolution will open up in the potentialities of the machine as an instrument of warfare. The writer of the present article does not wish it to be supposed that he is endeavoring completely to lay down axioms as to the military future of aircraft of a positive character, or that he pretends to be in a position to formulate a cut-and-dried constructive program; his intention is rather to give something in the nature of a lead in the direction in which it appears development may be logically anticipated.

THE PRIMARY AND SECONDARY FUNCTIONS OF THE AERONAUTICAL ARM.

It is generally recognized that in its employment in connection with military operations a most valuable property of the flying machine or aeroplane is its mobility; it is, in fact, mobile to a degree that can scarcely have been dreamt of in warfare of the past. When, therefore, we look for uses in coöperation with any army in the field in which the aeroplane may show to advantage, we naturally turn to examine the duties at present fulfilled by the cavalry, hitherto the arm to be employed wherever mobility is of importance. Thus it is well recognized that one of the main duties for which the cavalry have hitherto been responsible—namely, reconnaissance—is a duty to which aircraft are eminently suited. It is at the outset important to realize that the cavalry, in face of the improvements in small arms and artillery, with the advent of the armored motor car, and with the greater mobility of the main bodies of troops in modern warfare, have been finding the difficulties of effective reconnaissance continually on the increase. It is stated by one of the greatest authorities on the subject that of the reports sent in by cavalry patrols not more than 1 per cent. are of any use to the commanding officer, usually owing to fact having anticipated the receipt of the information; in other words, the whole process of tactical reconnaissance by cavalry has become far too slow to keep pace with the conditions of modern warfare.

So far as the writer is aware, there has, up to the present, been no serious attempt to work out in complete detail the duties that can be undertaken by aircraft, or to define in specification form by any process of logic the types

of machine that will be necessary at the outset to deal with the various duties so postulated. It is necessary to say *at the outset*, in view of the fact that if today we had a perfect organization based on existing conditions, the first great power to be similarly equipped would require to be answered in the form of a further equipment especially directed to his destruction, and so (as in the evolution of the Navy) we shall probably have in due time aerial destroyers and "super" destroyers, and again still larger and more heavily armed machines for the destruction of these.

The primary function of, and basic justification for, any arm is the execution of its duties in relation to other than its own kind; thus, though it is admittedly one of the first and most important duties of cavalry to drive the enemy's cavalry out of the field, and establish superiority, this is actually the secondary function of the cavalry arm; its primary function is the observation and harrying of the other arms of the Service. Again the primary function of a fleet is neither to hold nor defeat a hostile fleet, although this, its secondary function, is universally admitted to be its first and most important objective. Ultimately, in every case, there must be some primary purpose which gives rise to the need for any kind of fighting machine, apart from its power of offence or defence against its own kind; it is this primary purpose that imparts the inital impulse and direction to its development.

It is proposed forthwith to define the primary function of the aeronautical arm as comprised by its duties and actions relating to the three preëxisting arms of the Service, viz: the infantry, cavalry and artillery.* Its secondary function is defined as comprised by its duties in the attack on and defence from its like arm—*i.e.*, the destruction or countering of hostile aircraft.

It is necessary to be perfectly clear as to the above definitions. In considering, in the first instance, the comparative merits of the aeronautical and the older arms of the Service for any particular duty, as it is needful to do in order to justify, or otherwise, any particular type or usage, it is futile to import into the initial discussion the action or possible counter maneuvers of the enemy's aircraft; this latter may, or may not, eventually prove an important factor, but its influence, when taken into account, must be studied not only as touching the air service, in contemplation, but also at the same time as affecting the other arms of the Service (more particularly the cavalry) in its corresponding usage. In brief, as a matter of logic in discussing the functions and duties of the aeronautical arm and the type specifications of machines, by which its objects are to be secured, the primary function alone has to be considered. Subsequently, when a provisional scheme and specifications have been formulated, it is time to take count of the secondary function, and to endeavor by careful provision to forestall the enemy.

AEROPLANE *versus* DIRIGIBLE.

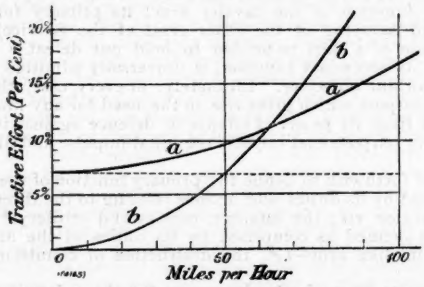
Two questions are involved in the consideration of the relative merits of the aeroplane and dirigible. We are firstly concerned with their respective advantages and disadvantages in relation to their primary function—namely, as instruments of reconnaissance, attack and defence; secondly, we have to take into account their secondary function—*i.e.*, their relative power of mutual destruction; whether, in fact, either can drive the other from the field, or whether each may have its own rôle to play in securing and holding the command of the air.

Before going into either of these questions in detail it is convenient to review a few of the facts by which limitations are imposed on the ultimate performance of either type of aircraft. We must avoid falling into any error by judging each too closely by its performance of today.

The all-important question of *speed* is a matter depending primarily on the lightness (*i.e.*, horsepower per given weight) of the prime mover, and the

* Also the navy and merchant marine where naval warfare is in question.

law of resistance. The horsepower per given weight available is roughly the same whichever type of air craft is in question, and any future advance in the art of motor construction tending to diminish weight will, we may presume, be equally available for either type. The laws of resistance of the aeroplane and dirigible are well understood; in the case of the former the resistance is approximated by a curve *a a*, Fig. 1, representing the sum of a resistance following the V-square law and a constant; the latter (the dirigible) may be taken as following the V-square law implicitly, Fig. 1, *b b*. Fig. 1, represents approximately actual values of the resistance coefficients, in tractive effort per cent., in machines of average size as they exist today for the speeds given in miles per hour.*



One salient fact is at once evident; the greater the horsepower available for a given engine weight the greater the advantage in the matter of speed in favor of the aeroplane. The highest speed of flight of an aeroplane attained today (through, *i.e.*, relatively to, the air) is already more than twice that of which the fastest dirigible is capable; there is every prospect that its advantage in this respect will increase rather than diminish with the march of progress.

Beyond the above, it is well understood that an increase in size is conducive to a reduction in the resistance coefficient; this applies to both aeroplane and dirigible. This fact has been one of the controlling considerations in dirigible design; no dirigible, other than of comparatively large size, has been found to be of real service. It is, moreover, evident that, in the case of some of the large Zeppelins, it will not be found practicable to go very much further in the direction of increase. Here again the aeroplane is at an advantage; we can in nowise regard the aeroplane of today as defining the limit of what can be reached.

It is abundantly manifest that the *dirigible is at a permanent disadvantage of not less than two to one in the matter of speed.*

The question of *range* and *duration* of flight is largely determined by petrol-carrying capacity. In the aeroplane both range and duration depend definitely upon the petrol supply holding out; in the case of the dirigible the same applies to a limited extent; but here the duration and, to a less extent; the distance can be greatly prolonged by reducing the speed to the minimum possible without jeopardizing the control. In the dirigible the gradual loss of buoyancy, due to the leakage and escape of hydrogen, is an

* The maximum speed attained by an airship is approximately 50 miles per hour; the maximum in the case of an aeroplane is considerably over 100 miles per hour; thus (Fig. 1) the tractive coefficient in the case of the aeroplane is very considerably greater than in the case of the airship. The reason for this is that the dead load in the airship—represented by the envelope and its appurtenances—is disproportionately great, and the proportion of the weight that can be devoted to the motive-power installation is relatively smaller than in the aeroplane. Were it not for this fact the airship would have held the advantage until speeds about 60 miles per hour had been reached and the aeroplane after.

independent determining factor. As a matter of fact, there is not (taking everything into account) much to choose between the two types of aircraft in the matter of range or radius of action; on the other hand, under favorable conditions, the dirigible has undoubtedly the advantage on the score of duration of flight. The maximum may be taken as about 24 hours in the case of the aeroplane, against 48 hours in the case of the dirigible. This may be taken as a fair indication of their relative capacity, though of no quantitative value as a guide to what is to be expected under service conditions. The possiblities of the future are here rather in favor of the airship; there is an absolute limit both of range and duration where the aeroplane is concerned.

On the question of *storage* or *housing* the advantage of the aeroplane is overwhelming; the aeroplane, especially if furnished with folding wings, can be stowed away in any ordinary shed or barn, whereas the "balloon hall" necessary for the safety of an airship is not only most costly, but is an unmistakable landmark for hostile aircraft at 20 miles distance. Again, bad weather effects the storage of an aeroplane but little, whereas the housing or getting out of an airship in a strong wind is a difficult and risky business, even under the best of conditions. A large Zeppelin may sometimes call for the services of 300 men.

The foregoing by no means exhausts the grounds of comparison, but is sufficient for the present purpose. It is scarcely necessary to point out the very great disparity of weight, and, incidental thereto, carrying capacity, between the two classes of machine; the large German Zeppelins have a gross weight, taken from their displacement, of 22 tons (military) up to 35 tons (naval); of the aeroplanes in service, practically all the military machines are less than 1 ton "tare," and most types do not exceed 1 ton gross—*i.e.*, with full complement, petrol, oil, &c.

If we were concerned with the primary function of the aeronautical arm alone, there appears to be no reason to doubt that both kinds of aircraft would have their place; the large airship has unquestionable advantages under suitable conditions: cruising at high altitudes over the battlefield, or over or in the rear of the enemy's lines, and reporting to headquarters by wireless every movement of strategic or tactical importance, it can render the most vital service. It is able to carry a complement of officers trained to observation, capable of giving an accurate interpretation of what they observe, and acting under most favorable conditions, such as are not possible in any aeroplane; it can move at some fifty miles per hour, if required, or remain to all intents and purposes stationary; it can follow continuously the course of events from sunrise to sunset, and remain the whole time in touch with headquarters, either for sending or receiving, on the other hand, for bearing despatches, for flying at low altitude within range of shot and shell, as may be necessary for detail reconnaissance or in cloudy or misty weather, for bringing machine-gun fire to bear on some important point or at a critical moment, &c., all these are duties for which the aeroplane is pre-eminently suited, as also for rapidly locating and signalling gun positions, directing fire, and duties of such like character.

It is more than questionable whether actual fighting is any part of the primary function of a dirigible at all; it is at least becoming apparent that bomb dropping is an entire misuse of the large airship; the results are incomparably small in view of the means employed, and can never affect decisively the course of any battle or campaign.

It is important to note that though it is possible effectively to armor an aeroplane, at least to be proof against small-arms fire, and that in any case the vulnerable target is small, the dirigible, presenting a mark larger than the proverbial haystack, cannot be effectively protected. In spite of the fact that injury to the envelope is not necessarily dangerous, such injury has already necessitated in more than one instance a hurried descent into a hostile country, with the effective loss of both vessel and crew. These are the considerations that render the dirigible at a formidable disadvantage when within reach of the enemy's guns.

We may now pass to the discussion of the secondary function of the aeronautical arm in its present relation—that is to say, we shall consider the question of aeroplane *versus* dirigible in armed conflict.

At the outset it is desirable to dispose of the much-worried analogy that crops up again and again when the present subject is discussed. Some of the most strenuous supporters of the airship as an auxiliary to the aeronautical service are fond of drawing a parallel between the air service and the Navy, the airship being put forward as analogous or comparable to the battleship or battle cruiser, and the aeroplane to the torpedo boat or destroyer. In the writer's opinion any such analogy is totally fallacious. The effective area of the target presented by an aeroplane is but a few square feet. The effective target area of a torpedo boat or destroyer is more than one hundred times as great. The time during which an aeroplane is visible and under fire, owing to its small size and high speed, is short compared to that of torpedo craft at sea.* The armament which a Zeppelin can bring to bear on an attacking aeroplane is confined to that which she can carry on a platform arranged on the top of the structure, since the hostile aeroplane making its attack from above can maneuver to remain, in billiard phraseology, "snookered" so far as the car and main armament are concerned. Beyond the above, the speed of the aeroplane is approximately double that of the airship, whereas the speed of a fast destroyer is not more than 20 or 25 per cent. superior to that of a fast and heavily-armored cruiser of modern type, and even this advantage is lost in heavy weather.

It will be realized in considering the above facts that the whole analogy breaks down—the continued existence of the battleship or cruiser in the face of torpedo craft does not in the least degree imply or involve the continuance of the airship as a logical necessity.

No. II.

AEROPLANE *versus* DIRIGIBLE (*continued*).

Having in the preceding article devoted some attention to contrasting the respective merits and limitations of the aeroplane and airship or dirigible, and to disposing of the false analogy so frequently drawn between the air forces and the fleet, we pass to the consideration of their mutual relationship in matters of attack and defence. Firstly, it is evident that the attack will essentially be on the side of the aeroplane; the dirigible can do no more than act on the defensive. The great disparity of speed alone, whatever armament the airship may carry, settles this definitely; it is within the power of the aeroplane to choose precisely when, how, and where it will engage in conflict. The dirigible, like the submarine, is too slow to run the enemy to earth or to bring him to bay, and, to its disadvantage, cannot, like the submarine, make itself invisible and attack by stealth. Beyond this, its quarry (the aeroplane) is of small size, often scarcely visible at a mile or two distance, and when not actually in the air can be either concealed or efficiently protected. Any attempt at aggressive action on the part of the dirigible is totally and completely out of the question; it is in fact beyond the conceivable range of possibility.

On the other hand, if the airship is to continue as a factor in warfare at all, it must be able to defend itself against hostile aircraft, and in particular be capable of repelling the attack of the enemy's aeroplanes. Now the only power of defence possessed by a dirigible when attacked by an aeroplane is counter-attack by gun fire; hence the extent, character and distribution of its gun armament is one of the most important factors in its design.

In the earlier days of the development of the aeroplane, when its horsepower was but little in excess of the minimum required for the bare

* Added to this to detect the approach of a hostile aeroplane the sky has to be scanned in the three dimensions of space.

necessities of flight, its rate of ascent was so extremely slow (if it could be said to have any real rate of ascent at all) that it was commonly assumed that a dirigible, or airship, could seek safety in altitude. Today, however, many aeroplanes will make altitude at a speed of 700 feet or 800 feet per minute, thus being more than able to hold their own with the lighter-than-air machine, and can ascend to over 10,000 feet altitude (even twice this height has been reached); again having the dirigible at a disadvantage.

The method by which an aeroplane may most effectively attack a dirigible is a matter that remains for future experience to settle. If the aeroplane pilot is prepared to sacrifice himself, and has at his disposal a powerful machine of modern design, no dirigible can stand against him. If, as a matter of experience in actual service, men are found of sufficient grit and grim determination to adopt ramming tactics, and to hurl themselves and their craft bodily at the gas bag of the dirigible, its destruction is immediate and complete. There is no defence possible against this mode of attack. The crew of the dirigible may not have even the most slender chance of stopping the aeroplane by machine-gun fire; the attack can be made from above by a steep *vol plané* or a vertical dive. In the case of a large airship of the Zeppelin type, even with machine guns mounted "on the roof," the chances of defeating such an attack are remote; the speed of a machine descending vertically, or steeply, is approximately that of its limiting velocity—commonly about 150 miles per hour—leaving a very brief period in which to score a hit. Beyond this, no ordinarily fatal hit is effective under the conditions in question; no injury to the motive-power installation is of the least effect as a stopper, and the pilot is in almost perfect security in his position behind the engine. If by an exceptional chance he should be wounded, he is still able to effect his purpose, unless totally disabled.

The steep or vertical descent is admittedly a dangerous feat of airmanship, but it is not intrinsically dangerous; the risk involved is due to the structural stresses to which the machine is subjected when "flattening out." These, it is well known, may become excessive; any objection on the score of danger has obviously no weight whatever under the conditions contemplated.

It is an open question whether airmen will always be found ready to step forward at the critical moment to go to certain death, and so the general feasibility of ramming tactics must for the time being remain in doubt. However, there are many other modes of attack open to the aeroplane pilot, all more or less untried at present; unquestionably also there are still other methods that will in due course be devised. In the case of the non-rigid dirigible, as in the ordinary spherical balloon, it is almost certain that a hundred or so yards of barbed wire trailed beneath an aeroplane would be a quite sufficient weapon; equally effective would be an incendiary shell, or a rocket, presuming any part of the envelope to be hit. Ordinarily small-arm or machine-gun fire is comparatively ineffective, since the bullet holes are, in any case, small, and in some of the modern machines repairs can be effected without coming to earth. However, even rifle fire has proved sufficient to bring a balloon down. It is evident that the weak point of any dirigible or airship is its liability to attack from above; in the non-rigid type, without going to the length of any elaborate apparatus, and without endangering the attacking aeroplane, almost *any* angular and weighty object dropped from a height cannot fail to be of conclusive effect if it fairly hits the envelope, and likewise in the case of the rigid type—such as the Zeppelin—the structure would not stand up under a blow from, say, a steel bar of any ordinary stock section of 70 pounds or 80 pounds weight dropped from a height of 200 feet or 300 feet. Without saying that the above are suitable methods of attack, it may be claimed that they fairly indicate the inherent

weakness of the dirigible in face of attack by an aeroplane of sufficient power to master it in the matter of altitude. There are methods not mentioned here which are actually in use or in contemplation, but which, for obvious reasons, require to be treated as confidential. It is, however, in the writer's opinion, quite unnecessary to carry the matter further; the weaknesses of the dirigible on the defensive are so great and of such a character as to render it quite unfit to remain an active participant in aerial warfare. It may escape for a time, and may render a certain amount of useful service, but only thanks to the circumstance that the number of high-powered, fast-climbing aeroplanes is comparatively limited, and to the fact that scientific methods of attack have not yet been fully worked out or put into practice. However, even today the finest of Germany's fleet of Zeppelins would be absolutely at the mercy of a modern aeroplane in the hands of a man prepared to make his one and last sacrifice. So fragile and combustible a contrivance as a dirigible, whether rigid or non-rigid, can never, in the writer's opinion, survive in the face of the rapid development of the modern aeroplane and the engines of offence with which before long it will be furnished.

Before proceeding to the broader considerations, it has been thought desirable to dispose of the airship as a factor in the aeronautical service—its dismissal being an initial simplification. It is not altogether important whether or not this conclusion turns out to be literally true. It may be that, in spite of all that has been put forward, the large airship may retain some degree of utility, possibly reserving its appearance until after the annihilation of the enemy's air fleet; even if this be so, the main conclusions will be unaffected. It is the aeroplane, and the aeroplane only, either as a reconnaissance or a fighting machine, acting independently or in flights or squadrons, that in effect will constitute the aeronautical Arm; and whether the considerations we discuss are strategic or tactical, it is the potential capabilities and limitations of the aeroplane that we require to keep constantly in mind.

STRATEGIC AND TACTICAL USES OF THE AERONAUTICAL ARM.

In the present distribution of the cavalry Arm, the distinction between the strategic and tactical uses of cavalry is clearly recognized. For purely tactical purposes it is customary to attach one or more squadrons, usually a regiment of cavalry, to each infantry division. The main cavalry force is known as the independent cavalry, and constitutes a separate command, taking general instructions from the headquarters staff. The independent cavalry may be engaged in operations of strategic import, as in the conduct of a reconnaissance in force, or in the execution of a wide turning or out-flanking movement, or in the countering of such a movement on the part of the enemy. Alternatively, it may be employed in its tactical capacity, its full weight being thrown at some critical moment into the fighting line, it may be to attack and destroy the cavalry of the enemy, to raid and capture or put out of action his artillery, to harass him in retreat, or to convert a retreat into a rout. The divisional cavalry are, generally speaking, employed for the latter—tactical—duties only.

Similarly, aircraft are capable of employment in duties of both strategic and tactical import, and accordingly will probably need to be divided into divisional and independent commands. For example, in reconnaissance there is the strategic scouting, whose function is to inform the headquarters staff of the main disposition and movements of the enemy's forces, positions of his depots, magazines, &c., points of concentration and strength of his reserves, and last, but not least, his main and perhaps auxiliary lines of communication. On the tactical side there are many duties to be carried out, in some cases analogous to those at present performed by cavalry; in other cases duties that we may almost regard as

new, and brought into being by the peculiar power and capabilities of the new Arm; in the main, these are such as would indicate control by the divisional commander.

THE STRATEGIC SCOUT AND ITS DUTIES.

The strategic value of the aeroplane depends mainly upon its utility for the purpose of reconnaissance; briefly, it is its value as an informer, rather than as a fighter, that is of service to the headquarters staff. The duties of a machine thus acting are necessarily of an entirely different character from those of a machine employed in the minor operations of the field, whether for tactical scouting, direction of gun fire, or otherwise. Not only will the flight range, as determined by its petrol capacity, be a far more important factor in its design, since it will require to operate over a large area, and to cover long distances over the enemy's territory, where any renewal of fuel supply is impossible, but also its flight speed must be such as to render it reasonably secure against pursuit. Anything serious in the direction of armor or armament will be entirely out of place, since under no circumstances will such a machine be required to act in a combative capacity; its defence lies in its speed. It appears from all reports that the duties in question are such as to require an observer (probably a staff officer) of mature knowledge from a military standpoint, with considerable flying experience, possessing something of an intuition for reading the meaning of the incomplete and fragmentary indications that are obtainable from high altitude observation. It is evidently not impossible for a strategic scout (as we may term the machine under discussion) to descend to low altitude in pursuit of more accurate and precise information; but it is always to be remembered that any such maneuver is dangerous to an unarmored machine; it may be too easily shot down or destroyed by shrapnel. In this latter event it must be regarded as having failed in its purpose. The possession of a wireless installation may be assumed, but, in the event of the machine being lost, the fact that reports had already been transmitted to headquarters would in no way mean that the machine had completely fulfilled its mission.

The work done by the strategic scout thus comprises the gleaning of information hitherto only to be obtained by a reconnaissance in force—that is to say, by a large force of cavalry with supports of horse artillery and infantry, often involving considerable fighting and loss. It is quite improbable that aeroplane scouting will prove an entire substitute for such reconnaissance; it may be said that cavalry can *feel* and *act* where the air scout can only *see* and *report*, but, as a prelude to cavalry reconnaissance, and as an auxiliary thereto, the services of the strategic scout should prove of the utmost utility. It will, at least, enable the cavalry force acting at a distance from its base, frequently in the rear of the enemy, to keep in constant touch with the general at headquarters, and relieve the despatch rider of one of his most difficult and dangerous tasks. In service of this character it would seem probable that a *flight* or *squadron* of aeroplanes would be temporarily or permanently attached to the independent cavalry, as in the case of the supports representing the other two Arms of the Service. Under these circumstances the command of the combined force would remain, as at present, with the cavalry leader.

No. III.

THE AEROPLANE AS AN AUXILIARY TO TACTICAL OPERATIONS.

The aeroplane in its employment in connection with tactical operations finds itself under conditions entirely different from those discussed in the preceding section; its duties are of a more varied character, and

involve flying at lower altitudes than are compatible with security. It is likely to be almost continuously under fire, and, according to some of the experiences of the present war, it has almost as much to fear in this respect from its friends as its foes. Whereas the strategic reconnaissance machine is able to perform all its most useful work at high altitude, and will avoid as far as possible the attention of, or actual contact with, the enemy, and evade pursuit by flight. The tactical machine acting under the divisional command, whether engaged in local reconnaissance or in locating or directing gun fire, or in other duties, must be prepared at once to tackle the enemy, and, in brief, to interfere as much as possible with the hostile aeroplane service. Under certain circumstances the instructions will undoubtedly be to make the aircraft of the enemy the first objective.

It is more than probable that it is in connection with the varied duties that in the future must fall to the Fourth Arm in its tactical usage, that differentiation of type and specialization will eventually become the most marked. At present practically no attempt in the direction of specialization has taken place. It is true the different machines in service vary considerably, and those responsible for the construction and specification of Service aeroplanes have already begun to talk of "reconnaissance machines" and "fighting machines;" but the distinction is one that has scarcely yet penetrated to the field of operations. When all has been said, differentiation of type must, from the Service standpoint, be looked upon as an evil, only to be justified when, and to the extent that, service conditions prove it to be necessary. So far even the broad distinction between machines for strategic reconnaissance and for tactical operations has scarcely been drawn or received recognition. The military aeroplane of today is something like the frontiersman's knife—made for nothing in particular, used for everything in general.

For the purpose of directing artillery fire the experience of the present war has shown the aeroplane to be effective almost beyond the most sanguine expectations. For this purpose it appears to have established its utility beyond question. Its duties in this respect may be regarded as a special branch of local reconnaissance, its function being to locate the objective and signal its whereabouts to the gun batteries to which it is attached; further to report and correct inaccuracies of fire. The exact mode or modes of signalling adopted do not so far appear to have been definitely disclosed. Some reports give the aeroplane as turning sharply when over the enemy's position; according to other accounts a smoke bomb of some kind is let fall to indicate the position to be attacked; other reports, again, mention lights as being used. It appears that lamps of sufficient power to be visible in daylight are actually being employed by the German aircraft. Possibly all these methods are in use experimentally, or different kinds of signals may be used for different purposes, to indicate initially the position, and subsequently to give corrections, either as to direction or range. Whatever the methods employed may be (and the details do not much concern us at the moment), they seem to be quite effective, and, it may be presumed, very considerably increase the fighting value of the guns. More than this, the value of aeroplane work will be relatively greater the longer the range; in fact, it may in future be found possible to employ heavy artillery of long range under conditions in which, without the help of the aeroplane, it would be comparatively useless. As an illustration, there is nothing today to prevent a long-range battery, well served by its aeroplanes, from effectively shelling an enemy without knowing in the least the character of its objective—*i. e.*, whether an infantry force or position, a body of cavalry or the enemy's guns. In the present war the aeroplane appears to have been utilized by the German army, as a matter of regular routine, as an auxiliary to the artillery in the manner indicated. It has been reported again and again that the

appearance of an aeroplane overhead has been the immediate prelude to the bursting of shrapnel, frequently the very first shell being so accurately placed as to indicate that the method of signalling, and, in fact, the whole performance, must have been well thought out and equally well rehearsed.

It is well understood that the determination of the distance of an aeroplane of *known size* with approximate accuracy is a matter of perfect simplicity. Thus, if the aeroplane be flying fairly overhead, or directly towards or away from the observer, and the span be a known dimension, then by measuring the optical angle presented by the span, the distance or range is given by simple proportion. For example, holding a foot-rule square in front of one at arm's length—approximately 20 inches from the eye—the span, known to be, say, 36 feet, subtends an angle represented by, say, ½ inch on the scale; the distance is $20 \times 36 \div 0.5 = 1{,}440$ feet. Using such rough-and-ready "apparatus," the degree of accuracy to be expected is not great; however, the writer has found it quite sufficient to determine the altitude of a machine to within 5 or 6 per cent. of the truth. If for the observer's arm and foot-rule we substitute a low-powered telescope or binocular of, say, 2 or 3 diameters magnification, with micrometer cross wires, with which to follow up the apparent reduction in span of a receding aeroplane, until some prearranged signal is given, the range could undoubtedly be determined easily to within 2 or 3 per cent. At 1 mile distance this means a degree of accuracy represented by a maximum error of about 40 yards, or sufficient to enable shrapnel to be dropped right on the mark. Parenthetically, it may be pointed out that the same method will enable the range of a hostile aeroplane to be determined, provided the type be identified, and its leading dimensions are known; it also suggests the importance of not flying exactly towards or away from, or exactly broadside to, any position of the enemy guarded by aeroplane (or balloon) artillery; flying end-on to the enemy is also to be deprecated on the ground of fixity of direction.

ATTACK BY GUN FIRE.

An aeroplane operating in a hostile country is liable to attack by rifle and machine-gun fire, also by shell fire from special aeroplane artillery. It has comparatively little to fear from field artillery owing to the want of handiness of the ordinary field gun. The "laying" of a field piece is far too clumsy a business to permit of its effective use on so small and rapidly moving a target as presented by an aeroplane in flight, though it may be effective when used against a dirigible. With regard to rifle or machine-gun (small-bore) fire, calculation shows that aircraft is absolutely safe at an altitude of somewhat over 7,000 feet; it is in that region that the top of the trajectory lies for vertical shooting.

The duties of a strategic scout on long-distance work would, without doubt, permit of flying at such a high altitude, and it may be added that, although absolute immunity is not reached at less than about 7,000 feet, a solitary aeroplane can only present a very unprofitable target at far lower altitudes. In fact, it may be taken that at, say, 5,000 feet or 6,000 feet, the amount of small-arm ammunition that would be wasted in bringing down an aeroplane would be enormous. Not only would the velocity become so reduced as to render a "hit" capable of but little mischief, but the time of flight of the bullet, rising vertically to this altitude, would be about 8 or 9 seconds, and the distance moved by the aeroplane 1,000 feet, more or less. Therefore it would be necessary to fire into quite a different part of the heavens from that in which the aeroplane was seen, something akin to sighting into the Great Bear to hit the Pole Star. Beyond this the gyroscopic drift of a bullet fired vertically is nil, against some 30 feet or 40 feet under normal conditions;* also the

*The normal sighting of a rifle is arranged partially to correct for the gyroscopic drift.

error due to the earth's rotation is a matter of about 30 feet westward, and cannot be allowed for without taking reference to the compass bearing. Taking all these things into account, it is evident that for the infantryman or gunner not specially trained, the task of bringing down an aeroplane flying at high altitude is no light one, especially when we recall the fact that for every inclination and bearing of the line of sight the conditions differ. In designing the mounting of aeroplane-stopping artillery or machine guns, it would be possible to render the sighting corrections for such items as gyroscopic drift and earth's rotation automatic; this could be done without difficulty, and would mean the elimination of errors whose combined value may amount to something like 60 feet at 6,000 feet altitude—*i. e.*, an angular magnitude represented roughly by the apparent diameter of the sun or moon.

The height to which aircraft artillery will carry is by no means subject to the same limitation as that of the small-bore machine gun or rifle, the resistance of the air being many times greater than that due to gravity. Thus the ordinary rifle bullet, at 2,000 foot-seconds muzzle velocity, would carry to a height of over 60,000 feet *in vacuo*, instead of approximately 7,000 feet actual. If we take the case of a 1-pounder having the same velocity, its effective vertical range is well over 12,000 feet, and from that caliber upwards the range will, in practice, be more a question of the shell being properly directed than whether it will attain the height. At the best, firing from the ground at an aeroplane at high altitude will require skilful gunnery, and when near the limit of the trajectory nothing but sheer good luck will render a hit effective. The angle of "lead" it is necessary to give to allow for the velocity of flight, as already stated, is one of the difficulties of high-altitude shooting. This angle is only constant so long as the velocity of the projectile is constant, assuming (as fairly represents the conditions) the flight speed not to vary; at extreme heights the velocity of the projectile has fallen so low that a very slight error in range finding will be fatal to accuracy. The solution of this difficulty may be found in the employment of guns of about 3-inch bore (as already in use for airship defence)—*i. e.*, a 12-pounder or 15-pounder, with the concurrent advantage of a full shrapnel charge, and, in shot-gun terminology, a larger killing circle. The obvious disadvantages, however, of artillery, in place of a machine or other light automatic gun, lie in its want of portability and its unhandiness, difficulties that doubtless may be overcome, to some extent, in course of time.

All things considered, it would appear probable that attack on aeroplanes at high altitude from the ground may be found impracticable, or at least uncommercial. Not only have we to reckon with the various considerations above discussed, but also with the fact that, in our climate at least, not more than one day in four is sufficiently clear to render high-altitude shooting possible, and though it is true that an aeroplane, to make observation, cannot remain above or in the clouds, it presents but a poor mark under bad weather conditions.

An aeroplane operating at high altitude will probably need to be hunted and driven off or destroyed by armed machines of its own kind.

DEFENCE FROM GUN FIRE.

It is manifestly not possible for an aeroplane to perform all the duties required of it, in connection with tactical operations at high altitude,* and whenever it descends below 5,000 feet, or thereabouts, it is liable to attack from beneath; in fact, at such moderate altitudes it must be considered as being under fire—mainly from machine gun and rifle—the

*For military purposes we may take the term "high altitude" as defined by the effective vertical range of small-arm fire—in other words, as denoting an altitude of 5,000 feet or 6,000 feet or more.

whole time it is over or within range of the enemy's lines. Protection from the rifle bullet may be obtained in either of two ways; the most vital portions of the machine, including the motor, the pilot, and gunner, can only be effectively protected by armor plate; the remainder of the machine, including the wing members, the tail members, and portions of the fusilage not protected by armor, also the controls, struts, and the propeller, can be so constructed as to be *transparent* to rifle fire—that is to say, all these parts should be so designed that bullets will pass through without doing more than local injury and without serious effect on the strength or flying power of the machine as a whole; in certain cases components will require to be duplicated in order to realize this intention. It is important to understand clearly that any intermediate course is fatal. Either the bullet must be definitely resisted and stopped, or it must be let through with the least possible resistance; it is for the designer to decide in respect of each component which policy he will adopt. The thickness of the armor required will depend very much upon the minimum altitude at which, in the presence of the enemy, it is desired to fly; also upon the particular type of rifle and ammunition brought to bear. There is a great deal of difference in penetrative power, for example, between the round-nosed and pointed bullets used in an otherwise identical cartridge.

If it were not for the consideration of the weight of armor, there is no doubt that an altitude of about 1,000 feet would be found very well suited for most of the ordinary tactical duties of the aeroplane. At such an altitude, however, the thickness of steel plate necessary becomes too serious an item for the present-day machine, even allowing for the very excellent and highly efficient bullet-proof treated steel that is now available; at the altitude in question the minimum thickness that will stop a 0.303 Mark VI, round-nose bullet is 3 mm. (⅛ inch), but, if attacked by the modern pointed-nose Mauser, nothing short of 5 mm. or 6 mm. is of avail. If we compromise somewhat in the matter of altitude and prescribe 2,000 feet as the minimum height for which protection is to be given, the figures become 2 mm. (about 14 S. W. gage) for the 0.303 round-nosed bullet, and for the pointed Mauser 3 mm. or slightly over; at present it is not expected that it will pay to armor a machine for the duties in question more heavily; thus we may take 2,000 feet as representing the lower altitude limit of ordinary military flying. Anything less than this will be referred to in the present series of articles as low-altitude flying. On this question of armor it cannot be too strongly insisted upon that anything less than the necessary thickness definitely to stop the projectile is worse than useless; a "mushroomed" bullet, possibly accompanied by a few detached fragments of steel, is infinitely more disagreeable and dangerous than a bullet that has not been upset.

An aeroplane armored in all its vitals with 3-mm. steel, and otherwise designed on the lines indicated, flying at not less than 2,000 feet altitude, will be extremely difficult to bring down; so much so, that unless its exposed structural members be literally riddled and shattered by rifle and machine gun, or unless a gun of larger caliber be brought to bear, it will be virtually impossible to effect its capture by gun fire alone.—"Engineering."

DESIGN OF HYDRO-AEROPLANE FLOATS, by G. H. MILLAR, B. A. Paper read at the joint meeting of the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, and the North-East Coast Institution of Engineers and Shipbuilders, July 8, 1914.—"Engineering," July 31, 1914.

This paper treats of this subject in detail. Calculations, diagrams and illustrations are given, with results of model experiments.

THE AIR BOMB.

A NEW METHOD OF MINING THE AIR AND OF THWARTING AN ATTACK BY FLYING MACHINE OR DIRIGIBLE.—THE INVENTOR'S EXPLANATION AND A CRITIC'S OBJECTION.

By Joseph A. Steinmetz and Carl Dienstbach.

—

AERIAL OFFENSE AND DEFENSE.

By Joseph A. Steinmetz.

Aerial warfare, like fighting on land or sea, resolves itself into offense and defense.

The defense of land areas, for example the very vulnerable works of the Panama Canal, against attack and destruction by air craft, can be successfully accomplished, as explained so fully by Mr. Dienstbach, by the use of aerial mines. This same scheme of defense would apply as well to the battleship fleet afloat, the units being so spaced that the balloons could not interfere or entangle when blown about in turbulent air.

The offensive action or attack to destroy, involves problems new and more difficult, and here Mr. Dienstbach very ably sums up some of the possible troubles in a theoretical action. The attack, for example, against a Zeppelin would be delivered by several swift aeroplanes directly as the arrow speeds to the mark. It is not contemplated to maneuver an aeroplane with the pendent bomb hanging free. At the moment before passing over the object to be destroyed the bomb is reeled out by gravity, and the speeding machine is across and beyond before the feed reel is checked. Using the enemy as the resistance body over which the wire is pulled permits a run out of a thousand feet or more before the fatal charge is exploded into the gas bag. Such an attack at night or in uncertain weather, foggy or windy, would be irresistible, and the opposing artillery would be at a serious disadvantage.

In a black night the destroying aeroplane would fish for the noise of the enemy in the void below and, no matter what the swing of its deadly tail, could soon hook and destroy the leviathan of the air.

The aeroplane artillery units thus far devised have not been mounted to repel attack from the rear, but rather in view of forward action.

In no sense does the Steinmetz aerial offensive device usurp the place of the artillery, but supplements it. This fact would be developed in an engagement between two aeroplanes mounting guns, such as the bow mounts of the Voisin, Benet-Mercier, Farman, Deperdussin and other French aircraft. The attack would involve a swift approach, and as was suggested in a recent newspaper review accredited to Lieut. Bellinger, operating our O. W. L. planes with our fleet at Vera Cruz, "one aeroplane could ram and destroy the other." This is too expensive and wasteful a process of elimination. The recent dreadful tragedy in Austria, when an aeroplane slit open and ignited a dirigible, was an example of ramming. Therefore with artillery-equipped aeroplanes in action and coming together at a mile-a-minute speed, the result must be either a successful disabling shot, a head-on crash, a quick bank, or a vault over.

The plane equipped with the Steinmetz bomb unit would rise over the enemy, disconcerting his range, and, letting slip at the instant of incidence the death-dealing tail, would finish the affair.

The weight of artillery units with ammunition runs into hundreds of pounds, whereas the trailing bomb and wire reel equipment complete weighs but 25 pounds, and can be used with light-weight aeroplanes by inexperienced civilian operators.

In time of war the units could be issued from stock in unlimited quantities and attached in an instant, without the delay and heavy expense of creating

and mounting untried guns, more or less of experimental models. Indeed, it will always be a serious matter to find and train sufficient aerial artillerists, and this shortage will be always in proportion to the growing need of gunners for the land and sea batteries.

There is another phase of the pendent-bomb destructive units not touched upon by Mr. Dienstbach; the attack at ground level in destroying the hangars and dirigibles at rest, igniting the gasoline and commissariat supplies, derailing troop trains, and crippling transports.

On water the attack could demoralize landing parties, smash the wireless of battleships, blow off the periscopes of submarines, and perform similar service, impossible at night by aeroplane artillery.

A quick mobilization for war of the air forces would include civilian aviators flying private craft and unfamiliar with artillery science.

In Germany owners of large motor trucks are subsidized as army transport units to serve in time of war. In some such manner must privately-owned air craft be counted as part of the aerial defense of nations.

Such an air force must be available at almost instant notice and must be lightly equipped and mobile, able to defend itself as well as to destroy.

The civilian aviators and raw recruits will not be skilled artillerists, but must, wasp-like, be able to strike and sting with pendent bomb delivering out of the blackness of the night down to the enemy their *coup-de-grace*.

—

A CRITICISM OF THE STEINMETZ SYSTEM OF AERIAL OFFENSE AND DEFENSE.

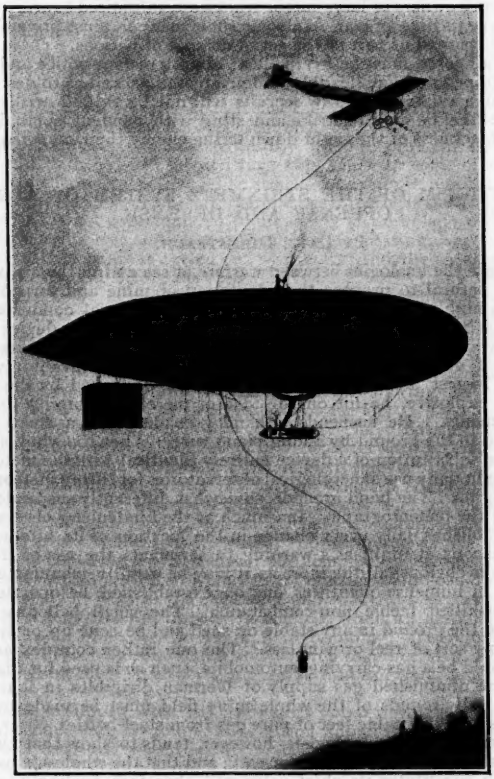
By Carl Dienstbach.

So close are the analogies between warfare at sea and in the air, it was no more than natural to propose the adaptation of mine and torpedo, which play such a highly important part in naval war, to aerial conditions. The thought has been amplified and perfected in an interesting device recently patented by an American, Mr. Joseph A. Steinmetz. This device has the advantage of great simplicity and cheapness. As its inventor was well aware the largest aerial dreadnought may be destroyed by the smallest amount of explosive, he hit on the idea of merely combining three well-known elements. He suspends a hand grenade from a small "pilot" balloon held to the ground by a long piano wire. When the wind is high he proposes the substitution of a device entirely identical with the meteorological box kite in daily use at aerological observatories for lifting meteorographs to great heights. The hand grenade, somewhat differently suspended, takes the place of the meteorograph. Inasmuch as the Lindenberg observatory in Germany publishes daily every change in the location of its kite wires and employs beacons at night as a warning to aeronauts, the use of the Steinmetz device is obvious, all the more as it may be readily manufactured and distributed in immense quantities, and once established, be operated by an army of unskilled feeble non-combatants. The small balloons may be sheltered on the ground in any stable or shed and be sent up or hauled in at will by any sort of reel or windlass. The one rather complex accessory required would be a gas-carrying automobile, such as is used for the replenishing of the diminished gas supply of German dirigibles in inaccessible places; for daily rounds of the whole mine field must be made to refresh the balloons by a few cubic feet of pure gas from steel bottles.

The experience of meteorologists, however, tends to show that the handling of kites is by no means simple or easy, and that the wholesale use of the device which constitutes its chief value will, therefore, be likely restricted to calm weather. This suggests at once another indispensable accessory—a signaling system to the multitude of unskilled operators for instantly passing the command to "haul in." Such an important decision may obviously not be left to their individual discretion.

A curious and entirely novel use seems to suggest itself here for wireless

telegraphy. Optical signals are not dependable; acoustic ones too audible; and signaling by wire is too expensive. But wireless is excellent for distributing intelligence. Its very essence is distribution, and it seems high time that this peculiarity, which for regular commercial telegraphing represents rather a necessary evil, should for the first time be turned to advantage in war. As the distances to be bridged from a central station are comparatively small, the reliability is irreproachable, and the simplest apparatus suffices. The receiver reduces itself to a "magic pillbox" before the eyes of the unskilled operator, with a little dial on which one single change indicates the instant for hauling in. Wireless, now so commonplace in its usual employment, becomes again such a marvel in the novel rôle that one wonders why its hidden possibilities are not more thoroughly exploited.



ATTACKING WITH PENDENT BOMB.

The value of the Steinmetz device is not diminished as much as it may seem by restricting its use to calm air, for the simple reason that the enemy's dreadnought dirigibles will obviously operate at night, and will pick out the

calmest of the generally calm nights for finding their objects of attack and casting their bombs with something like accuracy. The moral effect of expecting to run into a mine at any nook and corner will more than repay the outlay; especially, if it will restrain aircraft from operating in weather in which they are most to be feared.

As the result of the Steinmetz device lies entirely in quantity, a warning against its use in turbulent air seems justified. Observation officers in the baskets of military captive balloons in any wind are often hauled down seasick after having been blown about. It would not take a storm long to transform an aerial mine field into a hopeless tangle of live bombs which would presently come down on the heads of those that were to be protected.

The aerial mine is inferior to the sea mine not only in its vulnerability to currents, but also in its visibility. Furthermore, it cannot (at first sight) be more dangerous to aircraft than a sea mine would be to submarines, which, unlike ships, are likewise not restricted to one level of flotation. Against all these handicaps the air mine can oppose only its cheapness and lightness. The former quality allows its use in countless quantities, the latter covers not only one but many levels of flotation, as an aircraft striking a wire will most probably strike the mine as well, just because the wire will instantly cut into the soft outer material of the structure and, unless it tears, provide for itself a guide from which it cannot slip until it has hauled the mine at its end against the moving craft.

Visibility is a more serious drawback, as the first balloon sighted would be undoubtedly the signal for a Zeppelin to rise to its top level of flight, but that in itself would be protection to those below. But as efficient aiming requires comparatively moderate altitudes, the Zeppelin might not wish to rise higher than necessary above the level of that first balloon. It is at once seen how important it is to anchor these balloons at a variety of levels, all, of course, as high as practicable, by allotting the lengths of wire according to the skill or clumsiness of the operators. Discovering the balloons at night would be at best like guiding a steamer at night among icebergs. Compared to the pace of a modern Zeppelin, the *Titanic's* fatal speed was insignificant. It is seen at once how useful air mines will be in reducing the speed of attacking aircraft, in making it possible to spot them with searchlights and shoot at them.

Mr. Steinmetz also proposes to turn his mine into a torpedo, or means of offense, by omitting the small balloon and suspending the bomb by a long wire from a dirigible or an aeroplane. He thus intends to "hook" other aircraft with an explosive grappling device, by dragging the wire from above across the bulk of a dirigible or an aeroplane. The plan has the merit of simplicity; without previous alteration any aeroplane or dirigible may thus be equipped for attacking.

But its efficiency is far more problematical than the mining scheme. Unless the attacking craft follows a rigidly straight course for miles without change of speed, the bomb at the end of the long wire is bound to oscillate through an immense arc. Even so, the wind should rock the light bomb easily. If the attack requires lively maneuvering—as it naturally should with the enemy trying to dodge—the course of the bomb will be very erratic, and the wire's direction become so irregularly different from that of the attacking craft that the enemy's being hit will be as much a matter of accident as with a stationary mine. If it were possible to set a whole mine field moving—in other words, fly a whole flock of aeroplanes in close order, each dragging its bomb—the plan would evidently be even more efficient than stationary mines. But it would, obviously, quickly result in a general disastrous entanglement. A few widely-scattered bomb-dragging aircraft would on the other hand, be worse than a few widely-scattered mines. They would be more conspicuous and, moreover, at any possible range of their erratic weapons the point-blank high-angle fire of the enemy would be of deadly accuracy. Generally speaking, as meritorious as the modified mining idea may prove in the air under certain circumstances, as misplaced seems the

idea of aerial torpedo attack. For this there is no object, because, unlike at sea, in the air a shell hit is just as deadly as a torpedo hit.—"Scientific American."

OIL AND OIL ENGINES.

OILS FOR DIFFERENT USES.

A good all-round red oil for general lubrication made of Western or asphalt crudes will show 23 to 24 gravity, about 395 flash and 250 to 295 viscosity, while an oil used for the same purposes made from Pennsylvania crudes will show about 30½ gravity, with the other points about the same except the viscosity, which will be lower. Competitive tables showing comparative viscosities of oils are not to be relied upon unless the temperatures at which the tests were made are the same.

Heretofore it has been custom on the part of oil salesmen to recommend for high-speed motors, dynamos, planers, etc., oils ranging in gravity from 30 to 32, flash 380 to 480, viscosity 180 to 225; an oil for gas-engine use ranging in gravity from 23 to 25, flash 390 to 420, viscosity 200 to 350; general machine work, light line shafts, etc., a 23 to 26 gravity oil, 360 to 395 flash and 150 to 295 viscosity; steam-cylinder stock for pressures up to 150 pounds, a 600 stock with about 6 per cent. tallow, for over 150-pounds pressure a 650 stock with 8 per cent. tallow, and for superheated steam but a very small portion of tallow with 625 stock. With too much tallow in superheated steam, steric acid is formed, which adheres to the cylinder walls and cuts the rings. The flash of a cylinder stock should not be below 500; the fire test is around 650; the Pennsylvania auto oils range in gravity from 30½ to 31, flash about 415, viscosity 215 to 225, amber color. For crusher bearings a cylinder stock compounded with a cheap black oil is generally used; for light spindle work, a water-white oil of about 34 gravity, 340 flash, low viscosity of 85 to 100. However, as previously suggested, with the new characteristics being developed in oils, new standards are doubtless being created and lubricants will be selected more on the basis of what they will do than on what they show as to gravity, flash, viscosity, etc.

Oils for turbine lubrication must not emulsify with water, and those used in transformers and conditions where electricity is a consideration, must be free from conducting substances. For these purposes filtered oils are required. In the steam turbine the oil is exposed to such high speed and, consequently, high intermolecular friction, that it will change in character after a certain period of use. Further, the nature of the lubricant must be such that it will quickly settle and separate from the water of condensation with which it becomes mixed so that it can be used again. The reason why developments along this line are so slow is because mechanical engineers are handicapped in their lack of knowledge on oil matters, and because, heretofore, lubrication has not involved to any appreciable extent the chemical character of the lubricant.

In a combustion engine the oil is not only constantly exposed to high speed and friction, but also to high temperatures. Both of these conditions tend to form substances rich in carbon by either decomposition or polymerization. The troubles are that oils will deposit carbon in the cylinders and start corrosion on the metal surfaces, and the spaces between the spark plugs become clogged. When applied to a vertical gas engine the oil will be divided into two parts, one working into the upper part of the cylinder above the piston, and the balance flowing back into the oil chamber below the piston. The part which comes into the cylinder

is subject to high temperature, and the part which runs back, to high friction and some heat. In both cases the oil is greatly taxed chemically. With an ideal oil, that part which comes into the upper part of the cylinder should burn up completely without residuum, and the part which runs back should not form any asphalt or gum.

It is claimed that much trouble arises in getting results from good oils on account of a lack of scientific compounding of one oil with another. Oftentimes, it is a case of internal friction and disturbance in the oil itself due to the combining or attempting to combine two nonaffinity oils. The dealer in attempting to produce a certain gravity and viscosity by combining one grade of light oil with a grade of heavy oil without the necessary instruments and facilities to determine the physical and chemical constituents of each oil, and without knowing whether the two oils are produced from the same crudes, does not know what kind of an oil he is getting. True, this is bringing the discussion down to a fine point, perhaps too fine to be of value in general machine-shop and factory work. In a large plant and in the operation of high-powered machinery the right oil is a big item. The above shows how futile it is for a buyer or large consumer to depend on specification purchases for results. It is a question for the oil producer and his engineer working in conjunction with the engineer or millwright of the plant to be supplied. Aside from the considerations of temperature of the bearing and the viscosity and wearing qualities of the oil, serious attention must be given to the design or construction of the bearing in relation to the duty imposed, the nature of the bearing lining, and the effectiveness of the lubricating devices and ways to keep an oil film between the surfaces of the bearing and the revolving shaft.—"Power."

OIL-CARRYING STEAMER "SAN ISIDORO."—"Engineering," Aug. 7, 1914.—This steamer is fully described, especially the arrangements for carrying and handling the oil fuel, heating arrangements in tanks, etc. This vessel represents results of years of experience in operation, design and construction of oil-carrying vessels.

LECTURE ON THE OIL INDUSTRY OF MEXICO,

At Oil Exhibition, Earl's Court, March 25th.

(Chairman, John Purdy, Esq.)

By R. P. BROUSSON, ESQ.

HISTORY OF OIL IN MEXICO IN ITS EARLY STAGES.

Legend says that the Totonac Indians, one of the Aztec tribes, wandering along the shore of the Gulf of Mexico found patches of chapopote (a heavy asphaltic oil) washed up by the sea.

Later on the Spanish Crown made a grant of certain territories in New Spain (Mexico), including the oil springs thereon. This probably refers to San Jose de las Rusias in the present State of Tamaulipas.

In the summer of 1868 Dr. Autray, who, perhaps, is better known as the discoverer of Angostura Bitters, discovered the oil springs of Cugas (Furbero), near Papantla. He exploited the oil by making a tunnel into the side of the hill from which the oil exuded. He set up a still and supplied the local demand for illuminating oil.

In his excavations he came across several miniature idols buried in the asphalt, which indicated that it had been a place of pilgrimage of worship in very early times.

His business unfortunately did not prosper, the transportation of all material to the place of operations and the product after refining being too expensive to allow of a profitable enterprise. His friends in Mexico City withdrew their support and the business came to an end.

Between 1880 and 1883 two companies began to drill at Cerro Viejo and Chapopote, in the Tuxpan district. Each company (one of which was backed by the "Boston Post") succeeded in bringing in a producing well. These wells were situated 8 to 10 miles apart, and the deepest is said to be about 700 feet. They have continued to gently flow practically to the present day. Two stills were erected on one of the properties, and there is a vague report that some oil was refined and sold.

Between 1899 and 1902 the Mexican Petroleum and Liquid Fuel Company (English interest) drilled some 18,000 feet of hole in the Tecoluta Valley, just to the south of Cugas (Furbero).

About the same time Messrs. Doheny and Canfield came from California and started operations at Ebano, some fifty miles to the west of Tampico, on the railway from Tampico to San Luis Potosi, and brought in some small wells.

In the winter 1902–1903 the Furbero group (the Oil Fields of Mexico Company) drilled their first well at Cugas (Furbero), which came in a flowing well, and in the same year the Pearson interest began drilling in the southern end of the State of Vera Cruz, near Jaltipan and Amesquite, in the canton (county) of Minatitlan.

In the same year (1902) the London Oil Trust and Mr. Johnson, of New York, each drilled a well at Chapopote and Cerro Viejo. The former was drilled to 600 feet, which showed no oil at the time, but on examination some four years later it was found oil had seeped into the well and was gasing slightly. By the latter a small intermittently-flowing well was brought in at about 900 feet. Unfortunately, through lack of funds, the work on these properties was suspended.

Meanwhile, the Pearson interest was successful in bringing in a good field at San Cristobal, in the canton of Minatitlan, and to which I will refer again presently.

The Doheny interest moved their operations from Ebano to Cerro de las Pez (some 2 miles to the south), which is a volcanic neck. Geologists were of the opinion that it would be impossible to find a good field under such conditions, but time proved otherwise. Here they brought in their first large well on 4th April, 1904, which still continues to flow at the rate of from 300 to 1,000 barrels per day.

THE GEOLOGY OF MEXICAN OIL.

In Northern Vera Cruz there is a coastal belt between the sea and the eastern Sierra Madre, on which we find recent deposits along the sea coast, succeeded in turn by older and older Tertiaries, until the western flank of the Sierra Madre is reached, which is composed of Rudistes limestone.

The age of this limestone is more or less equivalent to that of our English chalk. This limestone, however, is not found at all in England, though it is found in the Mediterranean basin.

The oil-bearing bed is a limestone, lying either in the marls just above the main Rudistes limestone, or, as found in the best wells, the oil-bearing bed is the highest portion of the main limestone itself.

These beds are fortunately overlaid by a great thickness (2,000 to 3,000 feet) of almost pure marl, and form an ideal impervious cover for the oil. These marls are poor in fossils, but near the top some foraminiferal

limestones occur, which indicate that at least this upper part of the marls is of Tertiary age.

The limestone beds become more frequent and the fossils more abundant as we rise in the Tertiary beds.

Northern Vera Cruz has proved previous geological ideas regarding the detrimental relation of volcanic necks and dykes to the oil horizon to be not so prejudicial as previously supposed.

In fact, in certain of the fields in Northern Vera Cruz the local concentration of the oil is due to the movement which took place when these necks and dykes were projected through the oil-bearing rocks.

Fears were expressed in the early drilling round these necks that the wells would strike the neck at a shallow depth. This has, in a number of cases, been disproved. The neck arising almost vertically, in fact, probably being of reduced area for some considerable depth.

The most recent discoveries have been apparently independent of necks or dykes. This does not entirely prove that they have had no influence on the accumulation of the oil, as there may be points at which the necks or dykes have never reached the surface.

There are numbers of necks and dykes in Northern Vera Cruz which have had no accumulating influence on the oil. Many of the oil fields may be independent of any such action.

DESCRIPTION OF THE FIELDS.

Production only began on a large scale in Mexico in 1907, when she first figures in the world's statistics with 1,000,000 barrels.

In Northern Vera Cruz one may say that out of some 70 promising localities for oil only some 19 have been tested, and out of these at least 15 have proved to be commercially productive.

The whole production is at present coming from 12 fields, 6 of which are controlled by the Pearson interests, who produced about half the 23,000,000 barrels which was Mexico's production for the past year (1913).

Up to the present there has been some 550 wells drilled since the beginning of exploitation for oil in Mexico, of which 130 have been drilled during the past year. The above production cannot in any way be taken to indicate the capacity of those wells which were productive, as the output is limited to the carrying capacity of the pipelines, and in the cases of the Panuco and Topila fields, to the barging facilities on the Panuco river.

The present fields are exceptionally well situated in being mostly within 30 miles of the sea, which has had a very beneficial effect in their quick development.

STATISTICS.

The following fields have been discovered in Northern Vera Cruz, and are at present in active exploitation: Tanguijo, Potrero del Llano, Tierra Amarilla, San Marcos, Los Naranjos and Furbero, which are entirely controlled and operated by the Pearson and affiliated interests.

The Ebano, Chijol and Juan Cassina fields are operated by the Doheny group or Mexican Petroleum Company, Ltd., interests.

The three fields, Topila, Chila Salinas and Panuco, are being operated by some 45 companies.

The Alamo field, belonging to the Penn-Mex, will shortly be in active exploitation.

In Southern Vera Cruz, San Cristobal, Soledad, Ixhuatlan and Tecuanapa fields are being vigorously exploited by the Pearson interests.

There are some 186 oil companies registered in Mexico, but there are only some 50 actually working.

The capital of 28 of these companies amounts to £20,902,666, of which 25 are producing. I mention this figure to show the magnitude of the interests involved.

CHARACTER OF OIL.

The character of Mexican oil is certainly asphaltic, but the public have rather run away with the idea that nearly all the oil is such as has been found to the north of Tampico, which is certainly of a high specific gravity (.982) and high viscosity. Heating coils have to be used in the storage tanks, and it has been found that it cannot be economically pumped through pipelines, it being cheaper to barge or transport in tank wagons. The Pearson interests have chiefly devoted themselves to regions further south, where the oil is distinctly better and can be economically pumped through pipelines.

The oil appears to become better and better as we go southward; at the southern end of the northern belt an oil is found having a specific gravity .894 viscosity, 143 secs. Redwood at 100 degrees F.

In the Isthmus of Tehuantepec, or southern belt, representative oils have the following qualities:

(1) Specific gravity .881, viscosity 108 Redwood.
(2) Specific gravity .852, viscosity 50 Redwood.
(3) Specific gravity .816, viscosity 30 Redwood.
(4) Specific gravity .792, viscosity — Redwood.

These oils contain large quantities of motor spirit and of high-grade illuminating oil; some of them are almost free from asphalt, which much facilitates the manufacture of a high-class lubricating oil.

In the State of San Luis Potosi the Pearson interests went in purely on geological structure and indications, and discovered very high-grade oil of specific gravity .783, so that it may be said that this company and their allies have a very large production of what may be considered middle-grade crude Mexican oil, together with practically all the fields producing the lighter class of oils.

PIPELINES AND RAILWAYS.

There are about 425 miles of pipeline laid down in Mexico, of which the greater part is 8-inch diameter; there are some 51 miles more under construction.

There are 86 miles of light railway in use in connection with the oil fields, and there are 35 miles under construction; in addition, some 54 miles are projected.

REFINERIES.

The Waters-Pierce Oil Company is one of the most important companies operating in Mexico, and have a refinery at Tampico.

The Doheny and Californian interests have an asphalt plant at Ebano, and are constructing a topping plant at Tampico.

Most of the other companies operating in Mexico are producing companies only, with the exception of the Mexican Eagle Oil Company, to which detailed reference will now be made.

THE MEXICAN EAGLE OIL COMPANY.

In 1902 the Pearson interests, as already stated, began their first search for oil in Southern Vera Cruz on the Isthmus of Tehuantepec, and acquired a large number of leases and blocks of land, after which they began drilling and were successful in five fields, so much so that a large refinery was constructed at Minatitlan, capable of dealing with some 15,000 to 25,000 barrels of oil daily. The first unit was operated in April, 1908.

Further extensive leases were secured, and after combining forces with the Pennsylvania Oil Company, active drilling operations were begun in

Northern Vera Cruz in 1906. The discovery well, San Diego, No. 3, was brought in in the spring of 1908, and on 4th July the never-to-be-forgotten well "Dos Bocas" came in.

The well was being drilled with a rotary rig, and after going through a very hard marl formation the bit went into shale about 3 feet (at 1,824 feet).

A heavy gas pressure developed, and in a few minutes the internal pressure manifested its force by bursting the wire-wrapped hose connecting the slush pumps with the drill stem. The oil began to come fast, probably at the rate of 10,000 to 12,000 barrels. Efforts to get the 4-inch pipe out were futile. In 20 minutes the well was completely beyond control.

Fissures began to appear in the ground, gas and oil coming through them. One opened directly under the boiler and ash pile, and although it had been pretty thoroughly drenched with water, started burning immediately, igniting the well, which by this time was throwing a solid 8-inch stream of oil far above the derrick.

The heavy English drill pipe was hurled out of the well in sections, some of it going 150 feet into the air. Later the 8-inch casing, which was anchored at the top but not set at the bottom, became loosened and fell into the hole, thus removing all chance of controlling the well.

It was impossible to go within 300 feet of the well as the heat was so great; the flames were estimated to be about 1,000 to 1,500 feet high and 50 to 60 feet diameter The fire was plainly visible in Tampico, and out at sea was often taken for the light from the Tampico Lighthouse. On 30th August, 58 days later, the well was reported to be extinguished, probably due to the tremendous caving which was taking place, and which momentarily choked it.

In January, 1910, the Tanguijo field was proved by a shallow well, which flowed an oil of specific gravity .92 from a 13-inch casing.

Within six days the Potrero del Llano, No. 1, well was brought in at a depth of 1,933 feet, which opened up another new field some 30 or 40 miles from the Tanguijo field.

On 27th December, 1910, the great Potrero del Llano, No. 4, probably the largest well in the world that has ever been got under control, came in at a depth of 1,911 feet, and ran wild for several weeks. The oil spread over some acres and burned in a number of pools, causing much vigilance and trouble in keeping the flames from the well.

Work was at once started on a mammoth earthen ground tank, and two 8-inch lead lines, connected at the casing head with 6-inch and 8-inch lines, were laid nearly to the reservoir. This immense reservoir covers 45 acres, and is more than 30 feet deep in the middle.

The well was flowing through the two 8-inch lines under 600 pounds pressure, and 300 pounds pressure was held in by the gate valve.

It was estimated that the daily flow was 125,000 barrels, and without question must have been over 100,000 barrels of oil. On 27th March this well had been flowing 90 days, and in that time more than 8,000,000 barrels of clean oil had flowed from it, no water or sand appearing.

It is at present shut down to about 40,000 barrels a day, which is the capacity of the pipe lines which take away the oil.

In December of 1911 another new field was discovered in Tierra Amarilla, 1½ miles from Potrero.

On 11th July, 1912, Alazon, No. 4, came in at 2,000 feet. This well was never completely drilled in, but in spite of this it produces some 25,000 barrels per day; it would probably give as much as Potrero del Llano if it were drilled a few feet deeper.

Later in the same year some good wells were brought in in the San Marcos field.

In October of last year (1913) a most promising field, 30 or 40 miles

away from Potrero, was found when Los Naranjos, No. 1, came in, and other very highly petrolific wells have been drilled since that date in this field.

The production of oil, as everyone here knows, is, however, only the first link in a long chain of commercial operations.

The Mexican Eagle Oil Company has over 200 miles of pipe lines (mostly of 8-inch capacity), miles of narrow-gage railway, and steel storage tanks aggregating over 2,000,000 barrels in Mexico. The large refinery at Minatitlan is capable of turning 1,400 tons of crude petroleum daily into a complete range of high-grade products—motor spirit, burning oils, lubricants, fuel oil, paraffin wax, and asphalt for roads.

Another refinery of even larger capacity is under construction at Tampico. This refinery, of which the first half should be ready in June, this year, will have a total throughout capacity of about 4,000 tons of petroleum per day.

An interesting equipment is that of the sea-loading lines at Tuxpan, where the water inside the bar is too shallow to allow the big Mexican Eagle steamer to come alongside and load. Accordingly pipe lines have been laid on the bed of the sea reaching out to a loading terminal about a mile and a half from the shore. Here the pipe lines are connected by flexible hose to the steamers laying at ocean moorings, and three or four vessels can be loaded at once from the storage tanks and pumping station on shore.

During 1913 more than 200 tank steamers have been loaded at Tuxpan in this way, and on the average each has been loaded and despatched within 2½ days.

The pumping and sea-line facilities enable a ship to be loaded at the rate of 10,000 tons per 24 hours.

The domestic trade of the Mexican Eagle Oil Company is in a very strong position today, supplying several of the Mexican railways and other large industries with petroleum product through over 160 depots. The refined-oil consumption of Mexico is well over 2,000 barrels per day. Naturally the railways of Mexico use fuel oil, and in one instance—which may be taken as typical—the saving derived from its adoption in the place of coal is no less than 40 per cent.

A company with such an output as the Mexican Eagle must, however, be prepared to meet the demands of the world's markets for oil in addition to developing its domestic trade, and the question of transport immediately arose. Two years ago a company was formed—the Eagle Oil Transport Company—which placed orders for 20 large tank steamers, of which 10 are giant vessels of over 15,500 tons dead-weight capacity. Those of my audience who have seen the *San Fraterno* in the cinematograph section of this Exhibition will have gathered something of the immense size of these vessels. It will suffice to mention that they burn Mexican oil fuel under their boilers, and have cargo pumps capable of handling 1,200 tons (9,000 barrels) per hour.

It will give some idea of the size of this fleet to remark that, placed end to end, the fleet would measure over 1¾ miles, and has a total carrying capacity of a quarter million tons per voyage. The chairman of the company—Lord Cowdray—remarked at a recent meeting that "it is only a question of time—and it will not be a long time—before oil will be the fuel used by the great passenger ships, as it is now extensively used by most of the navies of the world."

Oil-tank steamers have undoubtedly a fine and assured future in that they are fluid and mobile, and not dependent upon the vicissitudes of any particular oil field.

The Eagle Oil Transport Company have created a record not only in the size of their ships but in the celerity with which they have been con-

structed. Only a month ago there were two mammoth tankers of over 15,000 tons on trials the same day, and two further vessels of 9,000 tons were launched on the next two days, making a total of 50,000 tons in three days for one company.

Probably nothing in the last year or two has so contributed to make fuel oil a practical proposition for big steamship lines as the accession of this great fleet to the world's oil-transport facilities.

The immediate effect is reflected in the import figures of fuel oil for the United Kingdom. In the first nine months of 1913 the Anglo-Mexican Petroleum Products Company imported into this country 12,830,000 gallons of fuel oil, being more than the total from all other producing sources combined.

The Anglo-Mexican also distribute the products of the Mexican Eagle Company in all the markets of the world except Mexico.

Fuel oil has been demonstrated to give as much effective power per pound as 1½ pounds best steam coal for marine boilers, and as much as twice the amount of work than can be derived from coal for locomotives and land plants. But it is with industrial furnaces that oil in this country gets its best chance, the ratio of work done being 3 or even 4 to 1 in favor of oil as against coal or coke—weight for weight. These advantages are in each case supplemented by other important considerations which vitally affect the cost of working, such as better control and higher temperatures, saving in labor and space, ashes, clinker, etc.

An important product of Mexican oil fields is bitumen or asphalt. Mexican Eagle bitumen is found to possess just those qualities of adhesiveness and ductility which are requisite for the best road construction, and the company's products, "Mexphalte" and "Fluxphalte," are becoming widely and favorably known for this purpose both in this country and abroad. It will not be out of place to show one or two pictures of the important products of the Mexican fields as applied to roads.

It is a remarkable fact that Mexican oil has been shipped to two oil-producing countries, the United States and Russia, and to which Mexico stands third in output. It serves to suggest that at no distant date Mexico may contest with these countries for the distinction of second place in the list of the world's oil-producing territories.

The production of Mexican oil has arisen in six years from 1,000,000 to 23,000,000 barrels, and it is interesting to note that the rate of increase has not been surpassed by any of the great oil-producing States of the United States in their early stages.

This rapid development has meant a huge amount of work on the part of the pioneer companies, and when it is remembered that this work in Mexico has so far been confined to the State of Vera Cruz, and bearing in mind the prolific nature of the fields that have been proved, and the further fact that it is known that other States of the Mexican Republic are petroliferous, it is no exaggeration to assert that the oil resources of Mexico are but at the beginning of their ultimate prosperity.—"The Steamship."

THE HARRIS HEAVY-OIL MARINE ENGINE.

For a long time marine engineers have been looking for a reliable heavy-oil engine which is not only less complicated than the usual type of Diesel engine, but which is also without the serious faults which have so greatly militated against the widespread adoption of the Diesel engine on board ship. The general advantages of the Diesel engine, such as savings of weight and space and the remarkable economy of fuel consumption, are fully recognized, but so far these benefits have been

obtained only by the use of complicated valve and maneuvering gear requiring delicate adjustment and constant attention and the use of extreme ranges of temperature in the working cylinders which are detrimental to the cylinder walls, heads and pistons. A new heavy-oil engine has been developed, however, by the Harris Patents Company, Philadelphia, Pa., which has apparently overcome many of these objectionable features to a great extent and which also brings out a number of new features, both in the construction and in the method of operation, which vastly improve the working of the engine.

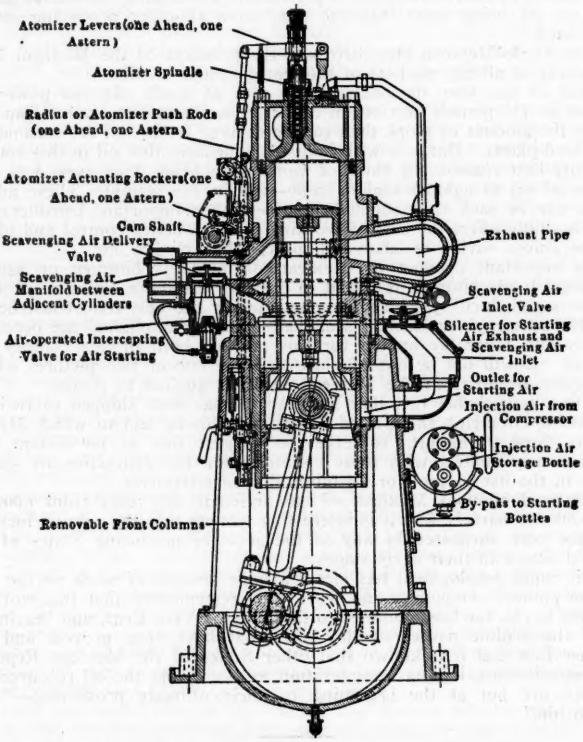

Atomizer Levers (one Ahead, one Astern)
Atomizer Spindle
Radius or Atomizer Push Rods (one Ahead, one Astern)
Atomizer Actuating Rockers (one Ahead, one Astern)
Cam Shaft
Scavenging Air Delivery Valve
Scavenging Air Manifold between Adjacent Cylinders
Air-operated Intercepting Valve for Air Starting
Removable Front Columns
Exhaust Pipe
Scavenging Air Inlet Valve
Silencer for Starting Air Exhaust and Scavenging Air Inlet
Outlet for Starting Air
Injection Air from Compressor
Injection Air Storage Bottle
By-pass to Starting Bottles

FIG. 1.—CROSS SECTION OF THE HARRIS ENGINE.

The Harris engine is of the two-cycle type, built in two, four, six or eight-cylinder units with a two-stage vertical air compressor worked off the crankshaft. In operation it is the nearest approach to the ordinary steam engine that we have yet seen. The entire control is by means of a single handwheel which, through interlocking devices that preclude mistakes on the part of the engineer, enable him to start the engine on compressed air and gradually build up its operation on oil while still working on air, or to reverse it from full speed ahead to full speed astern

in a few seconds. Further, the engine can be started immediately with the load on or it can be slowed down to a few revolutions per minute with the same certainty and with even greater ease than a steam engine of similar power. To fully understand how these results are obtained it is necessary to trace out the construction of the engine and its method of operation.

In place of the six or seven valves with their complicated valve gear, which are usually found in the cylinder head of a Diesel engine, the cylinder head of the Harris engine is entirely without valves, except for the single fuel atomizer by means of which the oil fuel is introduced to the cylinder. Stepped pistons are used, the enlarged extension of the main piston working in a cylinder below the working cylinder and acting not only as a scavenging pump for the adjacent cylinder, but also as an air motor for working under compressed air when starting or reversing the engine. In fact, the scavenging cylinders can still continue to run on compressed air while the working cylinders are performing their normal functions and operating on oil. The added advantage of this arrangement, aside from the fact that the working cylinders are not subject to the low temperatures caused by working on compressed air, lies in the fact that each scavenging piston, having a greater area than the working piston, allows the engine to be started with 175 pounds air pressure instead of the usual 800 to 1,000 pounds employed in Diesel engines, and, further, in starting and reversing the engine the atomizer valves do not operate while starting on air until the engineer wishes them to do so; consequently, all the usual by-pass valves are eliminated and the temperature of the fresh charge of air in the cylinder is quickly raised, owing to the absence of the chilling effect caused by an air blast entering through the atomizer valve without fuel on each stroke while starting on air.

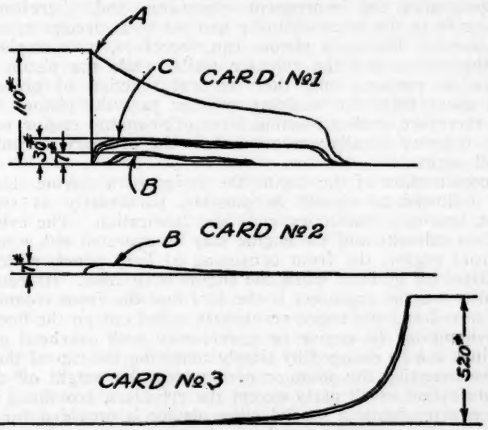


FIG. 4.—INDICATOR CARDS FROM HARRIS ENGINE.

A better understanding of this arrangement can be obtained by referring to the indicator cards Nos. 1, 2 and 3 shown in Fig. 4. Cards 1 and 2 were taken from the scavenging or step cylinder while starting on air without pumping oil to the working cylinders. The line *A*, Card 1, represents the first outward stroke or initial inlet of air on the scavenging piston, showing that it requires only 110 pounds per square inch to act

on the step piston to force upward the adjacent main working piston against its compression pressure of about 500 pounds per square inch. The reason why only a low pressure is required for this work is due to the enlarged area of the step piston against which the air expands. Line *B* represents the return of the above stroke of the step piston and shows that it performs its normal function of compressing a charge of scavenging air to 7 pounds per square inch. The line *C* represents the second and all consecutive upward strokes of the step piston, until the starting air is shut off by the engineer. The reason why only 30 pounds pressure on the step piston is required after the initial stroke is due to the fact that the pure air compressed in the working cylinder on the upward stroke of the piston expands on the downward stroke, thus assisting the air motor and recovering most of the work expended in compressing the air in the working cylinder. Card No. 3 was taken from the working cylinder at the same time that Card No. 1 was taken in the scavenging cylinder, and shows the compression and expansion of air in the working cylinder. Line *B* in Card 2 represented the normal function of the step piston delivered on the upward stroke, 7 pounds per square inch scavenging air pressure in starting air being admitted. This is the normal card which is given by the scavenging cylinder when running on oil.

The foregoing cards show that the step piston of the Harris engine performs three functions in three half revolutions, namely: first, one-half stroke downward, high-pressure air motor, 110 pounds; second, one-half stroke upward, scavenging pump, 7 pounds; third, one-half stroke downward, low-pressure air motor, 30 pounds.

Another advantage of the step-piston construction in the Harris engine is that the step or lower piston and the wrist pin in it are not subject to high temperatures and consequent expansion, and, therefore, can be made a nice fit in the lower cylinder and act as a circular crosshead for the main piston. The main pistons can, therefore, have ample clearance between themselves and the cylinder walls, while the piston rings are called upon to perform only their natural function of preventing the escape of gases from the working cylinder past the piston. This construction, therefore, makes possible a smooth-running engine without the noisy side flogging usually encountered in the ordinary "trunk" piston-type Diesel engine.

In the construction of the engine the design of a marine steam engine has been followed as closely as possible, particularly as regards the crankshaft, bearings, connecting rods and lubrication. The cylinders are supported on columns and the engine may be operated either as a closed or open-front engine, the front consisting of light panels which may be instantly lifted off by hand while the engine is running. A feature which will appeal to marine engineers is the fact that the front columns can be quickly removed and the entire crankshaft rolled out on the floor without further dismantling the engine or interference with overhead gear. The main bearings can be changed by simply removing the cap of the bearings without disconnecting the shaft or even taking the weight off the crankshaft. Lubrication of all parts except the cylinders, crosshead and wrist pins is by gravity, while a special oiling device is provided for the main bearings from below. The crank-pit drains lead to a common pump, which circulates the lubricating oil to a receiver separator, extracting dirt and water and thence passing the oil to a filter and supply tank.

Along the side of the engine is a single cam shaft on which are two cams for each cylinder, one for ahead and the other for astern motion. These cams actuate rockers, which in turn actuate push rods bearing on them to lift the atomizers in the cylinder heads. The push rods, however, are not brought into play until they are moved out through a small arc by a system of rods and crank levers connected to the control wheel.

If the control wheel is moved from mid-position toward the go-ahead position, it first admits air to an air-operated, intercepting valve admitting compressed air to the step piston, starting the engine on air. As the control wheel is advanced still further toward the ahead position the atomizer push rod over the ahead cam is moved out on its rocker and lifted by the cam, consequently admitting oil to the working cylinder. When the control wheel has reached the full-speed ahead position the lower end of the ahead push rod has been moved out to the end of its rocker and receives the full lift of the ahead cam, opening the atomizer valve to its fullest extent. This arrangement, however, not only affects the amount of lift of the atomizer, but also the time of the lift, which amounts to the same thing as advancing the spark in an automobile engine, with its consequent advantages.

The various parts of the engine are shown in Fig. 1. Scavenging air is admitted to the working cylinder through ports in its circumference, while the exhaust gases from the working cylinder pass out through ports located opposite the scavenging ports and so arranged that the piston opens and closes them at the correct time during its travel. Besides the scavenging air and exhaust ports in the cylinders, there is only one other opening in the working cylinder, and that is a small opening in the cylinder head for the admission of oil from the atomizer.

Oil is supplied to the atomizer by a variable-stroke pump for each cylinder. The variation of stroke is automatically controlled by a centrifugal governor, or the pumps may be operated by hand. The governor controls the discharge from the fuel pumps and does not lift the suction valves, as is commonly done in Diesel engines. Once the delivery pipes to the atomizers and suction supply from the service tank have been cleared of air there is always a solid stream of oil from the service tanks to the atomizers, and the slightest movement of the pump plunger produces a corresponding movement of the column of oil, forcing a definite quantity of oil into the atomizer, or, if the stroke be increased by the governor, a corresponding additional amount of oil would be supplied.

The oil is delivered from the service tank to the pumps under air pressure, which is taken care of by the engine, and may be anything from 5 to 100 pounds per square inch, making it immaterial where the service tank is located. There is no suction or pumping backwards, and if the governor cuts the pumps out of action entirely, the oil in the line is stationary and under pressure, too, ready to respond to the slightest movement of the pump plungers. It is claimed that hand pumping is necessary when starting, even after weeks of idleness. The stroke of each or all of the pumps may be varied either mechanically or by hand, all at once or each independently.

A unique device also permits the engineer to vary the speed of the engine instantaneously while the governor still maintains complete control of the operation of the engine at whatever speed the engineer wishes to operate it. It is also possible for the engineer to set the speed control at any predetermined speed before starting the engine, and when started it is claimed the engine will come to this predetermined speed and remain there. This speed control feature is especially useful in the case of a heavy head sea, when the engines are likely to race, and will perform the same work as that of an engineer at the throttle of a steam engine under similar circumstances.

In starting or reversing the Harris engine, air at from 175 to 300 pounds pressure acts on the step pistons, turning the engine over with its load on as long as the engineer desires to do so. After the first stroke, as previously explained, a pressure of only about 30 pounds is required; thus the engine is extremely economical in the use of compressed air when starting or reversing. After the momentum of the engine is built

up by working on air, the oil can be given to the main cylinders, the air still being allowed to act on the step pistons. This will augment the power being developed from the main pistons, and, if it is desired, both the main and step pistons can be acting at the same time, the former on oil and the latter on air. The action of the air on the step pistons in no way affects the working conditions in the working cylinder, nor does it affect the step piston's normal function of acting as a scavenging pump. This feature is a distinctive advantage for a marine engine, as it allows the vessel to respond more quickly and with more certainty in a case of reversing from full speed ahead to full speed astern.

Reversing is accomplished by moving a single rod on each cylinder and does not require the movement of the cam shaft or the lifting of valve levers off the cams by compressed air, as is usually necessary in the purely Diesel engine. In the Harris engine the same wheel or lever which admits the starting air and the fuel oil controls the movement of the rods. The engine has exactly the same functions and power when running either ahead or astern. The simplicity of the reversing mechanism, the additional power from the air motors, the unchanged conditions in the working cylinders and the fact that it is not necessary to shut off the fuel when reversing, all combine to make the Harris engine extremely simple and easy to handle.

The two-stage air compressor driven off the main shaft is mounted at one end of the engine with a control valve on the suction. The inter cooler between the first and second stages is in the water jacket of the second stage, while an after cooler is fitted between the second stage and the air bottles with an independent water circulation. Starting air bottles may be charged by the main engine while running, through a special type of reducing valve or by an auxiliary compressor. Bilge and circulating pumps are mounted diagonally on the forward end of the bed plate, and are driven optionally by eccentrics, or of the rotary type, the valves being fitted with quick-opening valve boxes.

Two marine sets have been running in the builder's shops for some time with excellent economy and without any signs of breakdown or trouble of any kind. The larger set is of 240 indicated horsepower. A smaller two-cylinder set has run successfully on Mexican crude oil of 19 gravity, a very thick, solid oil. The 240-horsepower engine weighs approximately 25,000 pounds. Its cylinders are 9 inches diameter with a stroke of 13 inches and at normal speed runs at 300 revolutions per minute.—"International Marine Engineering."

THE MARITIME FEATURES OF THE "CRUDE PETROLEUM" PROBLEM.

By Rear Admiral John R. Edwards, U. S. Navy, Washington, D. C.

Read Before the American Institute of Mining Engineers, Pittsburgh Meeting, October, 1914.

Introductory.—There are many interesting and important events connected with the petroleum problem. The remarkable men who conceived the thought of transporting petroleum by pipe line, conserving the by-products of the commodity, and conducting extended investigation and research whereby the flash point of the oil was raised, its cost reduced and its supply assured, are deserving of the gratitude of this nation.

It was primarily the success attained by Captain Lucas, after his comprehensive search for oil in Texas and Louisiana, that was the impelling

cause which prompted the Navy Department to conduct the extensive series of liquid fuel-oil tests that were made from 1901 to 1903. The sensational discovery of oil at Spindle Top made a deep impression upon Rear Admiral George W. Melville, then Engineer-in-Chief of the Navy, and the discovery of the vast oil field in Texas convinced him that, within a generation, if not within a decade, crude petroleum was going to play a very important part in warfare, and that the commodity might possibly develop into a necessary munition of war.

The United States' Commanding Position as a Petroleum Producer.—In the study of the various problems relating to the world's production of crude petroleum, the position of the United States is one of commanding importance, whether viewed from the industrial or the militiary aspect. The present yield of this country is practically double that of the rest of the world, and, in view of the productive and prospective fields possessed by various countries, together with the comprehensive and exhaustive search that has been made throughout the world for petroleum, it is extremely probable that this lead will be maintained for the next decade.

As regards the character of the crude-oil yield of different countries, America possesses the greater part of the supply that contains a paraffine base, and therefore a considerable portion at least of the American product produces the best illuminant. Of all the crude-oil distillates, kerosene is in many respects the most important, and the Appalachian product for this purpose is favored, particularly in the Far East, above that of any other petroleum yield of the world.

We are undoubtedly in advance of any other nation in the extent and character of our prospecting and drilling facilities, and this is attested by the fact that American experts are found in nearly all the other oil districts of the world, directing the activities of production.

In methods of refining our position is on a parity with others, if not a commanding one. We have been able to obtain from the crude product various distillates of as high character, and at as low a cost, as can be produced by the foreign refineries. New and important uses are being found for the by-products of crude oil, and our discoveries in this direction may undoubtedly be regarded as important as, if not superior to, those of our rivals.

In methods of land transportation our lead is undisputed. This should not be surprising, considering the extended and diversified experience that we have had in the construction of pipe lines, pumping stations and containing tanks, as compared with the relatively limited experience of the rest of the world.

The United States' Weakness as Regards Ocean Transportation.—There is one important feature of the fuel-oil problem, however, wherein we are lamentably weak, and that is the maritime distribution of the product from the terminals of the pipe lines to various important seaports of our own country, as well as to ports abroad.

The modern sea-going tankers that we possess are few in number as compared with those that fly the ensign of Great Britain. Our failure to convey or distribute crude oil in as efficient a manner as we produce, refine and transport the product, constitutes a serious industrial reproach to our commercial abilities. When viewed from a military standpoint, our lamentable dearth of ocean tankers and sea-going barges constitutes a great military weakness.

Our Lack of Sea-Going Oil Craft Entails Heavy Direct and Indirect Loss to American Industrial Activities.—It appears incongruous that a British corporation should find it a profitable venture to spend millions of dollars in prospecting for oil in Mexico, Ecuador, Colombia and other Central and South American republics, when our own capitalists ought

logically to undertake the practically exclusive development of those fields.

The British corporations engaged in petroleum development cannot possibly have the intimate professional knowledge and extended practical experience that is possessed by our own experts. Our banking interests are likewise undoubtedly as ready to advance capital in the exploitation of legitimate fuel-oil enterprises as the financial interests of England. It appears evident that it is only because the American maritime feature of the fuel-oil problem is so unsatisfactory that it has been possible for the Pearson Corporation in Mexico to compete against the American interests in that country.

As illustrative of the deplorable condition of affairs as regards the maritime feature of the crude-petroleum problem, it is pertinent to call attention to the fact that, when the Liquid-Fuel Board of the Navy was conducting its extended series of fuel-oil tests from 1901 to 1903, an investigation that extended over a period of 30 months, and an investigation wherein there were expended at least a quarter of a million dollars, there were several periods when the President of the Board was informed that, for two or three days at least, there was not one single American tanker carrying fuel oil between the Texas terminal ports and the leading seaports on the north Atlantic coast. Careful investigation was made to determine if such a condition of affairs actually existed, and, from the best information obtainable, there was one period, if not two, when it happened that every American sea-going tanker was either temporarily disabled, detained in port, or had met with some delay so that no oil vessel was steaming between the Gulf and north Atlantic ports.

It is possible that, at these two particular periods, one or two such tankers may have been proceeding with empty compartments to the Gulf for a cargo of oil. It may be stated as a fact, however, that in 1901 or 1902 a situation arose whereby, for at least a few days, not one gallon of crude oil was being transported by water from Texas to northern ports. There were, of course, during this special period, considerable quantities of oil being transported in barges from the terminal pipe lines and refineries at Baltimore, Point Breeze, Marcus Hook and Bayonne to other points on the Atlantic.

As bearing upon the question of the world's dearth of oil tankers, it may be well to call attention to the fact that, about 18 months ago, the Paymaster General of the Navy made an effort to find out the number and character of the tankers that could be chartered at short notice by the government. It was found at that time that it would not be possible to secure at short notice one single American tanker on the Atlantic coast; every tanker flying the American flag being required to convey the oil that was used for industrial and other purposes by regular consumers.

A still greater surprise was experienced when it was found that but one British tanker could be procured at that period, and that this vessel could only be chartered by the Navy Department by the payment of a rental of $575 per day, which rental did not include fuel and port charges. This rental had to be paid from the date the British tanker was chartered in London, and was to continue until the return of the vessel to the same port.

It seems surprising, if not astounding in view of the fact that we not only surpass the world as regards the yield of the crude-oil product, but that likewise we possess advanced methods of boring, improved processes of distilling, and incomparable methods of land transportation, that the maritime feature of the oil industry should have been neglected by this nation.

Profits of the Oil Industry Have Been in the Refining and Transportation of the Product.—In the study of the extensive and far-reaching report of the Commissioner of Corporations, as contained in the govern-

ment's brief against the Standard Oil Co., it is observed that the principal profits of that corporation have been in the refining and the transportation of the oil, and not in prospecting and drilling for the product. The distribution agencies, however, have been inadequate, except so far as they concerned districts fairly contiguous to pipe lines, refineries, and deep-water terminal points. At such particular points, which must necessarily be limited in number as compared with the rest of the country, the distributing facilities have been efficient, considering the expense, difficulty and hindrances encountered in distributing all inflammable hydrocarbon products. There is no doubt, however, that every interest concerned either in prospecting, boring, refining, or distributing crude oil has been very materially injured by our failure to control the distribution by sea.

The Importance of Petroleum as a Factor in Extending Our Foreign Market.—Fuel oil has played a very important part in extending our trade with China. The writer, in the course of his duties as a naval officer, spent about 6 years in Asiatic waters, and interviewed various American and British Consuls, as well as the leading merchants of the China coast, in reference to the far-reaching influence of the petroleum industry. The study of our trade development with China must cause one to be impressed with the fact that the three distinguishing agencies which have done most to cause the Land of Sinim to abandon many of its traditions and much of its medievalism have been the missionaries, modern surgery, and the work of the Standard Oil Co. In distributing throughout that country an illuminant that has been a direct boon to the people, the Standard Oil Co. has exerted an indirect influence that has been of far-reaching consequence in extending our trade relations with that Empire.

Light is a great civilizer, and the remarkably convenient, economical, and safe manner in which the Standard Oil product was distributed, even to the wilds of Hunan, was the forerunner of the entry in large quantities of other American products.

In the distribution of refined petroleum in cases rather than in bulk, our country attained for some time considerable success in the employment of sailing vessels. We lost, however, a great opportunity in not effecting legislation that would have retained to us this trade by regulating the export of the product, and that would have given to this nation a paramount control of the distribution of petroleum.

The writer was on the China coast about the period when the Russian oil interests, supported by the Rothschilds and other great banking interests of Europe, attempted to wrest the control of the petroleum industry from America. Modern steel oil tankers were built for the Rothschilds for this purpose, and large containing tanks were erected on shore at various points on the China coast. It was found, however, that the American product was so superior in quality as an illuminant, and it was so well contained and boxed, that it was practically impossible to supersede its use by the substitution of the Russian product.

It was not by a haphazard guess or by accident that the existing 5-gallon rectangular petroleum case was constructed. The form of the containing case, the material from which it is manufactured, the character of the soldering and the method of boxing and shipping constituted a development that represented heavy expenditure, extended experimentation, and practical knowledge upon the part of the Standard Oil experts.

In distributing this product, therefore, even unto the uttermost portions of the Chinese Empire, the Standard Oil Co. rendered a service of incalculable benefit, both to China and to America. If it had not been for the energy, efficiency, and tact displayed in developing our petroleum export trade, many looms in New England, and many furnaces in the Appa-

lachians that are now finding it a profitable venture to export their output to the Celestial Empire would be idle today.

It is believed that the American export trade of the future to Central and South America, Australia, and particularly to China, is greatly dependent upon the distribution or maritime feature of the fuel-oil problem. This phase of the oil problem is therefore a matter that is specially worthy of the consideration of the American Institute of Mining Engineers, for it is the mining engineer who is most intimately interested in the primary feature of the oil industry—and that is the prospecting phase.

There is something lamentable in the thought that, despite the fact that this country has a commanding lead in all but one of the various phases of the petroleum problem, America should fall down at the last stage, and that we should see our British cousins, through their superiority as regards the maritime feature, wresting from us a maritime activity of great value—an activity that logically should be possessed by America.

The Military Importance of the Maritime Phase.—It is not opportune at this time to speak of the military features of the distribution problem, since there are phases of the matter that intimately concern national defense. The fact is well known, however, to British naval experts, and mention has been made of the subject in the English press, that our navy is lamentably lacking in the oil tankers that will be required to supply American battleships and other naval vessels that have been designed to burn oil exclusively. The various publications of the Congress that are distributed both at home and abroad, tell of the number and character of American naval vessels that have been designed for an exclusively oil-fuel installation, and therefore our weakness as regards the number and character of the merchant and naval oil tankers that we possess must be well known to foreign military experts. The various publications issued by the government even tell, in detail, of the tonnage, cargo capacity, and other important structural features of these ships.

Our Inadequate Oil Reserve at all Our Industrial Centers in Considerable Part Due to Our Maritime Weakness.—The maritime feature is an important one, from whatever standpoint the question is considered. There are hundreds of industries in this country which would substitute petroleum for coal if an assured supply of the former combustible could be maintained. There are hundreds of industries that have experimented with petroleum with the intention of using it exclusively as a fuel, that have been compelled to return to coal, due to the impossibility of obtaining an assured supply of oil.

The cost and risk of transporting oil by cars constitute an insuperable bar to the distribution of the product in sufficient quantities to insure an adequate supply for large industries. Crude oil will, however, always be used for purposes wherein a substitute cannot be found, independent of the question of cost. It is, in fact, our dearth of water-transportation facilities that prevents the distribution of the product, and therefore limits the use of petroleum. There is no doubt that there are many important industries which, with the use of oil, would produce special articles that would find a ready and profitable sale in foreign countries, if they could be guaranteed that they would be able to get all the oil they required. It is well known that petroleum is an incomparable fuel for many industrial purposes, but no manufacturer dares to use the product except to a limited degree, unless his plant is so located that he can be assured of an adequate supply at other than a prohibitive cost.

Should Not an Export Duty be Placed upon Petroleum Products when Carried in Foreign Bottoms?—When it is considered that the United States furnishes about two-thirds of the world's yield of crude oil, and that it is somewhat probable that, at least in this country, the maximum of annual production has nearly been reached, unless there are vast undiscovered pools of oil at lower depths than we are now able to drill, it

ought to be possible for this nation to so regulate the export of the product as to conserve the industry in a manner that will best help ourselves, if not mankind. There are undoubtedly in the United States a sufficient number of steamship companies, railroads, and individual firms that would use all the oil produced in this country, if such plants could be assured of an adequate and reliable supply, and therefore the foreign export of oil may not be necessary in the disposal of the apparently large quantities produced.

In many industries the cost of the product is not a serious matter as compared with the particularly beneficial and industrial results that could be expected to accrue. It is all-important, however, in every enterprise, that, once an industry adopts a special form of fuel, such plants should be assured that an adequate supply of that fuel could be promptly obtained.

Many of the distillates of crude oil should even be regarded as munitions of war, and legislation should be enacted that would make it possible for us to prevent the export of oil at such times as we deemed advisable. Except for a brief period, it is extremely probable that, if we placed an export duty on petroleum, no permanent financial injury would accrue to any one interested in the drilling, refining, transportation, and distribution of the product. The writer has been told repeatedly, during the past 10 years, by various manufacturers and individuals, that it was solely the lack of assurance that an adequate supply of crude oil would be available that prevented them from using the product.

Probably no better way of helping to give the American merchant marine a reasonable share of the foreign oil-carrying trade could be devised than by placing an export duty on every barrel of oil exported from the United States in ships carrying a foreign flag. We are one nation that is unreservedly adopting the policy of fitting our battleships with an exclusively oil-fuel installation, and this installation is of such a character that, except at enormous expense, the structural change to coal-burning arrangements cannot be brought about. One of the most effective ways, therefore, of providing a supply at various points for naval purposes is to conserve the petroleum industry, by taxing the export of the product and by exercising the prerogative that logically belongs to us in controlling, to a limited degree, the sale of the commodity.

International comity and the law of nations sanction the policy of a nation placing an export duty on a commodity that is substantially controls. We are therefore justified in taking some radical means to control the maritime phase of the matter.

In the consideration of the problem of imposing an export duty upon petroleum, there are several phases of the question that merit thoughtful consideration and investigation. If serious thought is ever to be entertained of the proposition of imposing an export duty upon crude oil, the question may well be asked: "How will it affect our trade relations with China? Is the American illuminant of such superior quality that the Chinese would pay the additional cost that would be the result of such action? Have the foreign competitors of the Standard Oil Co. effected such improvements as regards refining the product that they can now furnish as good an illuminant as that which can be obtained from the paraffine-base product of the Appalachian region? Are our foreign competitors already making serious inroads into the sale of the American product in various countries? Would the loss of the petroleum trade of the foreign countries, and particularly the petroleum trade of China, be followed by a marked reduction of other American imports into those countries?" The question of an export duty is therefore one which admits of a wide divergence of opinion.

Conservation of Our Oil Resources.—The conservation of our oil industry can only be brought about by some national organization like the American Institute of Mining Engineers taking advanced ground upon

the subject, and urging that early and thoughtful action be taken in the matter. Various individual officials of the government, as well as individual experts, have urged such a course, but such individuals do not, in many respects, possess the machinery for being the proper central agency in bringing about such important action. The influence of the American Institute of Mining Engineers extends throughout the country, and, if it should recommend some thoughtful line of policy in the matter, there is no doubt that various commercial exchanges and maritime associations of the country would supplement the work of this Institute.

There is no doubt that the high purpose and urgent necessity of conserving the petroleum industry can be brought about in various ways, but the more study one gives to the matter the more impressed he becomes with the fact that, in the control of the maritime phase and in placing an export duty on oil shipped in foreign bottoms, it ought to be possible to do much, not only in conserving the industry, but in helping to bring about the restoration of the American Merchant Marine.

Efficiency of Our Oil Tank-Car Facilities as an Agency in the Distribution of Petroleum Products.—By reason of the wide extent of our country, the diversified character of its industries, and the limited number of existing oil pipe lines, the greater portion of the distribution of the crude-oil product will have to be done by cars. The existing design and arrangement of these cars represent extended and thoughtful development. The facilities for the safe and economical storage and handling of petroleum products are undoubtedly in many respects of the most efficient nature, and there is no doubt that all persons connected with the crude-oil industry are exceedingly receptive of counsel and advice that will improve the oil tank-car arrangements.

When there are considered the insurance and regulations, the danger attendant upon the transportation of oil by cars, together with the limited facilities for the storage of such combustibles in our various industrial cities, it becomes a question of paramount importance that wherever possible the car facilities should be supplemented in some manner, and that a greater distribution of the oil product can be brought about by barge or through some other maritime agency. However great may have been the shortcomings of those controlling the petroleum industry, there is no doubt that, so far as tank-car equipment and storage facilities are concerned, an exceedingly earnest effort has been made by the oil corporations to bring an adequate amount to the various industrial cities, and to store it in as convenient a location as possible. The oil-distributing companies, however, have been confronted with the problem that, at every important industrial center, there exists not only a dearth of oil tank cars, but a lack of freight-handling facilities. It has not therefore been possible, by reason of existing railroad terminal facilities, to give preference to the distribution and handling of crude oil when the railroad companies are confronted with the more serious and more important problem of handling the daily food supply of these great municipalities; and this, in general, is one of the reasons why manufacturers cannot get the oil they need.

Our Lack of Merchant Marine a Serious Bar to the Development of the Crude-Oil Industry.—One can well understand that it has been primarily due to the lack of suitable oil barges and tankers that makes the seagoing distribution, or maritime, phase of the problem a matter that concerns our industrial life. Under existing conditions the transportation of oil in American vessels to foreign ports is substantially a venture impossible of profit. On the Pacific coast it may now be possible; but, with the development of the Mexican fields and the opening of the Panama Canal, we may lose even that trade. The cost of operation of American-manned ships has been so great, as compared with the operation of foreign ships, that it is certain we cannot hold any foreign trade, and

therefore it has fallen into the hands of our foreign rivals. The indirect financial loss to this nation in the loss of the petroleum export trade has undoubtedly been of vast extent. American crude petroleum is one of the products that is favorably received, if not eagerly sought, in foreign countries, and therefore the control of this special trade is of far-reaching importance to our manufacturing interests at large. Following the importation of petroleum products into foreign countries, there has almost invariably been a progressive increase of imports of other American articles to such countries. It therefore appears that, if there is one industry that needed the support of the government, or even that should have been heavily subsidized, it is that relating to the carrying of crude oil in American-registered ships.

Nation's Reserve Stock of Crude Petroleum.—It is significant to note that the petroleum stocks on hand in the United States at the close of 1913 approached about 130,000,000 barrels, a quantity that would not meet the nation's existing consumption for a period exceeding eight months. On Jan. 1, 1913, the reserve stock was actually less than that on hand Jan. 1, 1912. During the past year, however, there has been a slight increase in the reserve stock, although drilling for the product was stimulated in every State in the Union as a result of the increased price obtained for substantially every distillate and by-product of crude oil. It is of exceeding commercial, if not military, interest, likewise, to remember that the yield for 1913 from every oil-producing State except California and Oklahoma was less than the yield of some previous year, despite the fact that progressively increased prices were obtained for the oil in every district of the country, and that oil fields which had been abandoned in previous years are now able, under existing conditions, to yield a profitable return upon the capital invested.

A very distinguished authority upon the California product has recently declared that, despite the continuous and careful research that has been made for oil in that commonwealth, the possible productive area of that State appears to be about 2,000 acres beyond that established in 1909, when Secretary Garfield, then the executive head of the Department of the Interior, ordered a survey to be made. He furthermore said that in all probability, nearly every crude-oil basin within that State had been located, and that there would be a constant drain and reduction in the reserve stocks that could be maintained there. In fact, another expert has asserted that, due to water intrusion and certain wasteful methods of production practiced in California, this country should be prepared to note a startling slump in the oil production of California. The wasteful manner in which drilling is being carried on in that State, taken in connection with the fact that the most important wells can henceforth be expected to show a progressively decreased supply of the product, affords some ground for the belief that the curve of production in that State may suddenly drop like the hump on the back of a camel.

As regards the thousands of miles of productive fields that are supposed to exist in Mexico, the United States Geological Survey, in its Advance Bulletin for 1914, states that, despite the phenomenal energy of crude-oil exploration work in Mexico, the fact remains that so far as the present supply is concerned the Mexican yield has been practically limited to a few large wells, and not to a very large number of smaller wells. It is questionable, also, whether many new wells are likely to be drilled under the peculiar conditions that exist in Mexico at present, and that may possibly exist for years, as regards shipments. It is extremely probable that the supply will not be sufficient to meet the demands of the numerous large-sized tankers that have been contracted for to carry the product from Mexico to England. It must further be considered that, with greater confidence developed as regards the Mexican supply, the price per barrel may increase rather than be reduced, because an assured supply from that

country will not only stimulate refining, but tend to increase the oil consumption throughout the world. At present the Mexican yield is but 5 per cent. of the total yield of the world, and there is substantial evidence that most of the promises as regards Mexican development are not likely to turn into performances. It is even going to be for some years quite a serious matter to safeguard the Mexican wells from destruction at the hands of brigands and insurrectos.

The Military, if not the Industrial, Necessity of Installing Additional Pipe Lines to Certain Points on the Atlantic Coast.—By reason of the fact that the vicinities of Cape Hatteras and Cape Cod constitute certain storm centers, the insurance companies of the United States charge additional rates on ships that pass near these storm points. These additional rates of insurance likewise apply to the cargoes carried by the vessels. While the rates for approved sailing-ship transportation are less than those demanded for approved steamship transportation, the fact remains that all classes of vessels, whether steam or sail, are made to pay an extra insurance charge of about 10 per cent. when plying within range of the lighthouses of Hatteras and Nantucket.

There are undoubtedly urgent military reasons, if there is not an industrial need, that the leading transporting oil companies should extend their pipe lines to some point on the Atlantic coast south of Hatteras, and to another point either on Narragansett or Massachusetts bay. An oil pipe line leading to New England ought to prove a paying venture at least in the course of a few years, by reason of the increased quantity that would be consumed there, and the higher prices that would be willingly paid by the manufacturers if they could be assured of an adequate and reliable supply.

In the manufacture of illuminating gas, crude oil is an important and essential constituent, and it ought to be possible, without in any manner impairing the financial interests of those engaged in oil transportation, to make the New England project a desirable investment. The number and character of the industrial cities between Bayonne and Boston, and the possible extent to which crude oil could be used in the industries of those cities, ought to warrant the building of a New England oil pipe line.

However numerous and however large may be the containing tanks that may be installed, but which must be supplied either by tank cars or by sea-going barge or ship, there will be periods, as long as we depend on tank cars and due to the railroad terminal conditions at all our leading industrial centers, when the reserve stock will be of such a limited nature as to prevent certain users from obtaining an adequate supply; and it is for this reason that there appears to be an industrial necessity for a new England oil pipe line.

The construction of a pipe line from the West Virginia fields to some point south of Hatteras—a port which possesses the deep-water facilities of Charleston, is a national necessity, and if necessary its construction should be subsidized by the government. The far-reaching influence of providing an ample supply of oil to naval vessels alone cannot be overestimated, and a pipe line to some point on the Atlantic coast south of Hatteras may eventually develop into a military necessity. Our seagoing battleships that are fitted with exclusively oil-fuel installations, together with numerous destroyers that burn oil exclusively, require terminal pipe line facilities at some point south of Cape Hatteras, and the construction of a pipe line from the West Virginia fields to Charleston ought to be given early consideration. Fortunately for the interests of the Navy, there are several oil pipe lines leading to Gulf ports.

The General Problem of the Conservation of Petroleum Should be Considered by a National Commission of Experts, Representative of all Interests Concerned in the Question.—Neither the direct value nor the indirect worth of the ocean oil-carrying trade to a nation may be within our

power to estimate. The far-reaching importance, however, of the maritime feature of the petroleum problem is best evidenced and manifested by the fact that, although the petroleum yield of the British possessions does not comprise even 1 per cent. of the world's production, there was appointed on July 30, 1912, by the British Ministry, a Royal Commission on Oil Fuel for the Navy. This Commission was headed by the ablest naval officer, in some respects, that has been borne on the Navy List of England since the days of Nelson.

In order to demonstrate the importance which Great Britain attached to the work of the Commission, the personnel of that body included the Director of Naval Construction, the Engineer-in-Chief of the Navy, representatives of the shipbuilding firms and shipping interests, together with representatives of every important interest concerned in the extension and development of the petroleum industry.

While this Commission has made several confidential *ad interim* or preliminary reports, it is extremely important to note that this distinguished array of experts has not yet found it possible to submit its final report to the British Ministry. These experts evidently believe that the more study that is given the matter, the more important appear the possibilities.

If there were impelling reasons upon the part of the British Ministry to appoint such a Commission, although England's distinctive industrial interest in the matter is primarily based upon the distribution feature of the oil product, it would appear much more important that this country should give equal consideration to the problem. In fact, however, it is the military possibilities of the problem that concern Great Britain; and should we not be more concerned as to this phase of the problem?

The Liquid-Fuel Board of the Navy, a Board which carried on the most exhaustive series of tests that have ever been conducted in determining the relative value of coal and oil as a fuel, made the following recommendation in submitting its report in 1903. It is pertinent to state that these tests continued over a period of 30 months, and that the direct and indirect expenditure involved in the work exceeded a quarter of a million dollars.

"In view of the fact that 48 per cent. of the world's output of crude petroleum is produced in the United States (it is now 63 per cent.), and that practically our entire yield is secured from fields which are in pipeline communication with important maritime and strategic ports, the Board considers that a joint commission, representing commercial, manufacturing, and maritime and naval interests, should be authorized by the Congress, whose provisions it would be to formulate such rules and regulations as would provide for the economical, efficient, enduring, and safe fuel installation."

Far-reaching as may have been the above recommendation, there have been such important developments in the petroleum problem during the past 10 years that it now appears more imperative than ever before that such a commission should be appointed. Its duties should be of a much more extensive nature than recommended by the Liquid-Fuel Board of the Navy. Its scope of inquiry should include every feature of development from prospecting for the product to the distribution of the commodity. Particularly should its work include the important problem of conserving this great industry to the benefit of our commerce and the defense of this nation.

This meeting of the American Institute of Mining Engineers affords an opportune time for giving some serious consideration to the question of conserving the petroleum industry, and to the appointment of a national Commission that would outline the nature of the work that should be entrusted to such a body.

AUXILIARIES.

HIGH SPEED BEARINGS.

Paper read before the North-East Coast Institution of Engineers and Shipbuilders by GERALD STONEY, F. R. S. Reprinted in "Engineering," Aug. 7, 1914. This is a carefully prepared and fully illustrated paper, going into details of designs, tests and actual results from various designs; methods of lubrication, cooling, etc. Marine turbine and thrust bearings are specially referred to.

It was pointed out that in marine turbines the journal speeds are much lower than on land and rarely exceed 30 feet per second, whilst the pressures are usually 80 to 100 pounds per square inch. There is a strong tendency to increase this latter figure, and it is probable that pressures of 150 pounds or even possibly 200 pounds per square inch could be used, especially if the oil temperature does not exceed 100 degrees to 110 degrees F., as is usual in marine work. The efficiency of the oil is limited by its loss of viscosity at high temperatures and by its liability to carbonize and thus cause deposits in the pipes and oil ways. In land practice temperatures of 120 degrees to 140 degrees F. are common, and it is not advisable to go above 150 degrees to 160 degrees F., as most oils seem liable to oxydize and cause deposit above this temperature, whilst at about 250 degrees F. the majority of oils cease to lubricate altogether as their viscosity becomes too low. In all high-speed bearings artificial means have to be used to carry off the heat, radiation alone being insufficient for this purpose. Water-jacketted bearings have been used in some cases, but it is not as satisfactory in general as the plan of supplying sufficient oil to carry off the heat. Oil coolers have, therefore, generally to be provided for the purpose. The heat to be removed is not only that caused by friction, but also the heat arising by conduction from the steel. The bearings near the condenser are cooled by the exhaust steam and heated by the gland steam.

WEIR'S PATENT ASH EJECTOR FOR SHIPS.

The accompanying illustrations show an improved design of ash ejectors for ships which has been patented by Messrs. G. & J. Weir, Ltd., engineers, Holm Foundry, Cathcart, Glasgow. As is well known, ash ejectors are at present employed for expelling overboard the ashes from the stokeholds of ships. The ashes are shoveled into hoppers, from which they gravitate into chambers, whence they are expelled by the sucking or impelling action of water, which is given the requisite velocity in a centrifugal pump and is delivered through nozzles, the water, together with the ashes, being delivered into a discharge nozzle and conveyed overboard. With ash ejectors of this type, if a high velocity of water is employed, much erosion is likely to occur in the eduction pipe, especially if there is a bend in this pipe. If a low water velocity is employed, a large quantity of water must be used, with the objection that, should there be a back flow of water from the sea through the eduction pipe, ash-delivery chamber, and ash hopper to the stokehold, the large pipe dimensions will allow of very rapid flooding of the stokehold. The object of this invention is to obtain the advantages appertaining to low-velocity water without the disadvantages. This invention consists in the employment of a high-velocity water jet, which is directed into and through the chamber into which the ashes gravitate from the charging hopper. The

high-velocity water ejects the ashes from this ash-gravitation chamber through a discharge nozzle into a main water pipe through which water is caused to circulate at a relatively low velocity. The ashes are conveyed along this main water pipe and discharged overboard with the water. The patentees employ a single high-velocity water jet which they direct through an admission nozzle into and through the ash-gravitation chamber. A discharge nozzle is arranged in axial alignment with the admission nozzle and with its inlet end communicating with the chamber opposite to the delivery end of the admission nozzle. The delivery end of the discharge nozzle is situated axially within the main water pipe, the high-velocity water, together with the ashes, being thus delivered into the center of the main water pipe. The main water pipe communicates at both ends with the sea, and circulation of sea water through it may be produced solely by the momentum of the high-pressure water which, with the ashes, is delivered into it from the discharge nozzle.

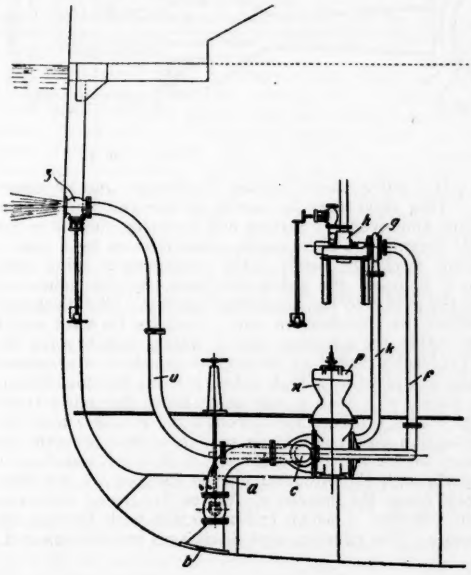


FIG. 1.

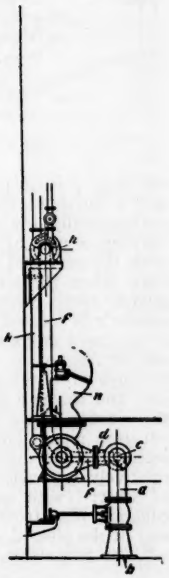


FIG 2.

In the accompanying drawings, Figs. 1 and 2 are diagrammatic views showing the ejector as installed on a steamship, Fig. 1 being a view looking along the ship and Fig. 2 a view looking across the ship. Fig. 3 is an enlarged elevation, partly in section, of the ejector, and Fig. 4 is a cross section on the line AA of Fig. 3, except for the bottom left-hand portion, which is a section on the line BB of Fig. 3. The pipe *a* is open to the sea at *b*. At *c* the pipe is branched, one branch *d* leading to the chamber *e* of the ejector, while the other branch *f* is the suction to the centrifugal pump *g*, which is driven by a steam turbine *h*. The discharge pipe *k* from the pump is led to the port *y* of the high-pressure water chamber *m*; *n* is the hopper into which the ashes are thrown through the grid *o* when

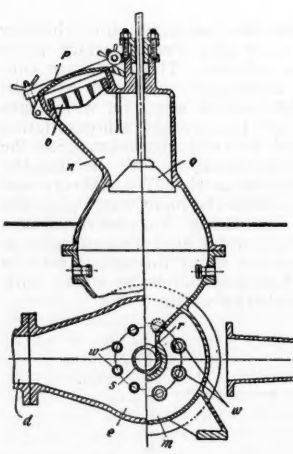


FIG. 4.

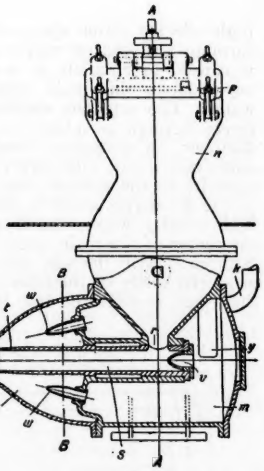


FIG. 3.

the door *p* is open. *q* is a valve which divides the hopper into an upper and a lower portion. This valve may be raised or lowered by hand or automatically, the means employed for raising and lowering the valve not forming a part of this invention. The hopper communicates by a port *r* with the rear end of the discharge nozzle *s*, the arrangement being such that, when the valve *q* is open, the ashes can pass, by the action of gravity alone, through the grid *o* to the discharge nozzle *s*. The discharge nozzle *s* is located within the chambers *m* and *e*, and its forward end *t* is arranged co-axially within the eduction pipe *u* which, just beyond the end of the nozzle, is preferably flared as shown. A nozzle *v* is arranged to allow of water being projected at a high velocity from the chamber *m* into and through the nozzle *s* in such a way as to move the ashes from the vicinity of the port *r* and project them through the nozzle *s* into the eduction pipe. The eduction pipe is of large section compared with the section of the discharge orifice of the nozzle *v*. A flow of water at a relatively low velocity through the eduction pipe is induced by the flow of water (with ashes) from the nozzle *s*. Water is drawn into the eduction pipe from the chamber *e* which communicates with the sea by way of the pipes *d*, *c* and *a*. The eduction pipe discharges into the sea at *z*. —"The Steamship."

AIR IN CONDENSERS.

Every engineer knows that air in a condenser is antagonistic to a high vacuum and high condensing efficiency, but few realize the importance of it. The question of air in a condenser is not so vital to the reciprocating engine, but with the steam turbine, in which advantage is taken of the heat units in the steam at lower pressures, to obtain such low pressure—more generally called high vacuum—the entry of air must be minimized.

The matter is referred to in "Power," which observes that the amount of air which enters a boiler depends upon the amount in solution in the feed water plus the amount added by the feed pump. The air in solution

in the feed water varies considerably and depends upon the nature of the source of the feed make-up, and the means for discharging the water of condensation from the condenser.

The amount of air added by a feed pump depends largely on the type of pump employed. With the old-fashioned, continuous-running, single-acting plunger pump, the air passed through is a maximum, because the suction pipe of the pump may often be open to the atmosphere. But in modern feed pumps which are independently driven and have their action float controlled so that the pump speed corresponds to the quantity of water to be dealt with, the suction inlet to the pump is always under water, and therefore, the least air passes through, such air as does pass through being in solution in the water.

As the liberation of air from the feed water is greatest when the water approaches the boiling point, it is desirable that an air-liberating device be combined with a feed-water heater through which the water passes before entering the boilers and thus prevent as far as possible the admission of air with the feed water.

Investigation has shown that nearly all the air which enters a condenser is due to the leakage of joints and glands subjected to pressure less than that of the atmosphere.

Minimum air leakage is experienced when the steam-condensing and power-producing apparatus consists of a steam turbine having tight glands, few accessible joints, and the connections to the condenser water sealed. Maximum air leakage is usually found in reciprocating engines, where numerous glands are subjected to a pressure lower than the atmosphere, and where auxiliary engines exhaust into the main condenser. In such plants the actual loss of power on the main unit by air leaking into the condenser through the auxiliary engines, is so great that it may exceed their total power, and, therefore the auxiliary engines should exhaust into a separate condenser at atmospheric pressure or into an exhaust-steam feed-water heater. This possible loss in power on the main unit is caused entirely by the "air drowning" of the tubes in the condenser, which results in a reduced rate of condensation and a less perfect vacuum.

If a condenser could be had containing no air, the ideal condensing possibilities would be realized and the condensation of steam under vacuum would be very simple, as the heat transfer through the tubes from the steam to the circulating water would be at a maximum for given conditions, thus producing the lowest temperature possible under such circumstances. Moreover, in the absence of air, the temperature throughout the condenser would be approximately the same, and no air pump or air-withdrawing device would be required. However, air being always present, it is necessary to consider how to keep the ratio of air in the condenser at a minimum.

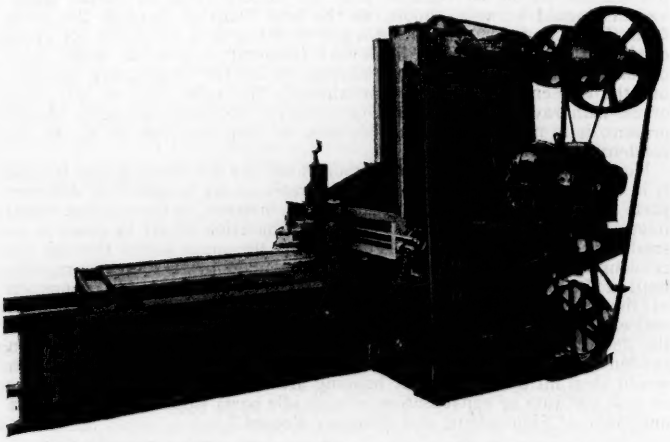
Normally, when a condenser is under load, the air entering and leaving it in a given time is the same; but the ratio of air to steam in different parts of the condenser varies greatly. For instance, at the exhaust steam inlet of a reasonably airtight system the proportion of air to steam is so small that its effect is almost negligible. As the vapor passes through the condenser and the steam condenses, the percentage of air increases rapidly, until at the air-pump suction the air forms a very considerable proportion of the mixture. The weight of air in a condenser does not depend entirely on the capacity of the air pump, but to a very large extent on the design of the condenser. The high surface efficiency in all modern condensers is largely due to the absence of idle corners or pockets which would soon fill up with the air hanging around the tubes, as the transfer of heat and rate of condensation in such idle parts would be reduced to a minimum.—"Shipbuilding and Shipping Record."

CONDENSER HEAT INTERCHANGES.

A considerable number of experiments have been carried out during recent years on the heat interchanges which take place within a surface condenser, and though the theory of condensation is by no means in a satisfactory state, some general results have been secured which make it possible to fix with reasonable precision the area of surface and the supply of circulating water required in practice. Thus it is commonly assumed that with clean tubes the rate of heat transmission may be about 500 British thermal units per square foot per hour per degree of difference in the temperature of the fluids between which the interchange of heat is being made. With dirty tubes the rate may fall to about one-half the above figure, and, as is well known, the presence of air in the steam greatly affects the rate of heat transmission. The actual rate of transmission per degree of difference in the temperature of the wall of the tube, however, is of course much greater, being with brass tubes of the usual thickness at the rate of about 12,000 British thermal units per square foot per hour per degree of difference of all temperatures. Our contemporary, "Engineering," calls attention to a series of experiments with a condenser using superheated steam, and the important point was established that within the limits of the experiments the British thermal unit transmitted per degree of temperature difference was unaltered by superheating. In these experiments the steam was applied at atmospheric pressure and the maximum amount of superheat was 30 degrees F. The rate of heat transmission was materially greater with the "downcomer" type of evaporator than it was with the standard type.—"Ship Building and Shipping Record."

CLEVELAND OPEN-SIDE PLANER.

The Cleveland Planer Works, 3150–3152 Superior Ave., Cleveland, Ohio, has recently built a special open-side planer for use on the United States Government torpedo-boat destroyer, tender No. 2, *Melville*. The installation of this planer between decks made it necessary for the over-all height not to exceed 8 feet 5 inches, which is 16 inches lower than the height



CLEVELAND OPEN-SIDE PLANER BUILT FOR THE U. S. GOVERNMENT.

of the regular 36-inch machine of this type. The design was finally worked out in such a way that the machine was built to meet the requirements and still have the full planing capacity of the standard machine.

Owing to the weight of the Cleveland open-side planers, no provision is necessary for bolting them to the foundation when set up under normal conditions. In the present case, however, it was necessary to provide for anchoring the planer owing to the roll of the ship. Referring to the illustration, it will be seen that power is provided by an individual electric motor which was built by the Reliance Electric & Engineering Co. under government specifications.—"Machinery."

CENTRIFUGAL-FAN CHARACTERISTICS.

By Frank L. Busey.* (Reprinted from "Power.")

SYNOPSIS—The performance of a fan depends largely upon its intelligent selection to meet the operating conditions. When to choose a multi-vane and a straight-blade fan. Static and total efficiencies are also defined.

The centrifugal fan is meeting with increasing application in general engineering practice, yet little attention has been paid by the majority of engineers to the advancement in design and construction of fans, or to the performance and selection to the various types. The electrical engineer now uses fans for generator cooling; the power-plant engineer for forced and induced draft as well as for the removal of ashes and the cooling of hot boiler rooms; and the operating engineer in industrial or public-building installations uses fans for heating, ventilating and cooling. The fan also has many special applications in various industries, such as furnishing blast to forges and furnaces; the removal of industrial waste by means of exhaust systems and the supplying of air for various drying and manufacturing processes.

The term "centrifugal fan" designates that form of construction commonly known as the steel-plate or multiblade type as distinguished from the positive blower type, such as the Root or Connersville. It is used to work against comparatively low pressures, ordinarily only a few ounces, or at most about 16 ounces, and is made up of a rotating arbor or plate to which are attached a series of blades. When this drum is rotated, the columns of air between the blades are given a centrifugal motion, delivering the air from the center to the wheel circumference.

In different forms, the centrifugal fan has been built for over 200 years, and even as far back as 1847 a Mr. Buckle presented data before the Institute of Mechanical Engineers for the design of fans which does not differ greatly from present practice. In 1872 the first complete treatise on the theory of the centrifugal fan was published by Daniel Murgue, engineer to the Colliery Company of Besseges, and this theory is still accepted by authorities on fan performance. These earlier fans were used largely for mine ventilation, and later for the ventilation of tunnels. At first they were simply for exhausting and were not fitted with a housing. In this way only the centrifugal velocity was employed, and no benefit was derived from the rotational velocity.

Some of the earliest fans are shown by Figs. 1 to 3, from which it will be noticed that some were fitted with a cone-shaped discharge, intended to reduce the velocity of the air. This same principle is still used in fans for mine ventilation. The earliest fans were built both with straight and with curved blades, but these blades were always long radially, and in some cases the housing was circular instead of spiral in shape; therefore, no benefit was obtained from the centrifugal action of the air within the fan wheel, and only the velocity of discharge was utilized.

* Deceased.

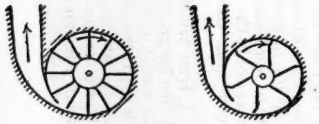


FIG.1
THE GUIBAL FAN AND CHIMNEY

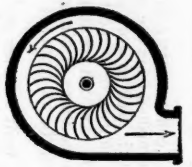
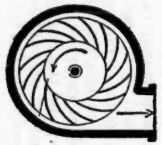


FIG.2
D'ANTHONAY FAN



FARCOT FAN

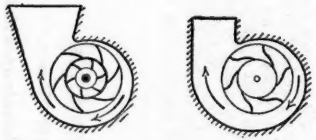


FIG.3
THE CAPELL FAN THE RANKINE FAN

FIG.4
THE SER FAN

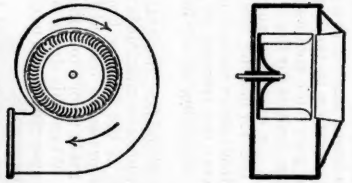


FIG.5
THE DAVIDSON FAN

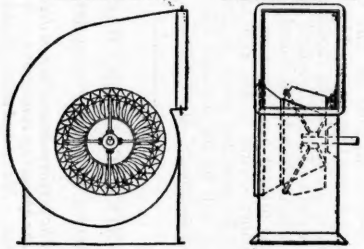


FIG.6 POWER
NIAGARA CONOIDAL FAN

DIFFERENT TYPES OF FANS.

One of the first multivane types using short curved blades was designed by Professor Ser, of Paris, about 1884, a sketch of which is shown in Fig. 4. Numerous other designs of curved-blade multivane fans were patented within the next 15 years, but the most widely known is the Davidson patent, more commonly called the Sirocco fan, shown in Fig. 5, which represents the fan as first patented, in 1900. Various American fan builders have brought out multivane fans within the last few years, generally differing in some essential feature from the Sirocco fan.

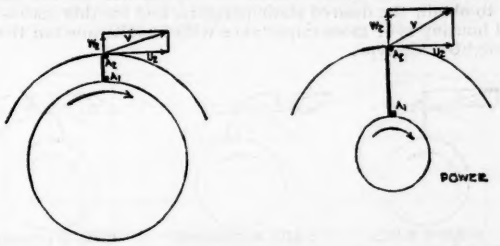


FIG. 7.—EFFECT OF CENTRIFUGAL ACTION IN FAN WHEELS.

One of these is the Niagara Conoidal fan, Fig. 6, which embodies two special features: First, the diverging cone effect is brought back into the fan housing, giving an actual lower outlet velocity and a consequent higher static pressure; secondly, the wheel is different in its design from anything previously built. The blades are of greater depth radially at the back than at the front, and are generated on a cone by a generatrix not parallel to the axis. By making the tangential velocity less at the back of the wheel than at the front the difference in centrifugal velocity is so balanced as to give an even pressure across the entire tip edge of the blade.

RELATIVE PERFORMANCE OF STRAIGHT AND CURVED-BLADE TYPES.

In any centrifugal fan there are two separate and independent sources of pressure: First, the centrifugal force due to the rotation of the air within the wheel; second, the kinetic energy contained in the air by virtue of its velocity upon leaving the periphery of the fan rotor. The action of the centrifugal force upon the particles of air within the fan wheel may be illustrated by the two diagrams in Fig. 7. Due to the centrifugal force, a particle of air at A, at the heel of the blade, will be thrown to the tip and given a velocity W_2. The resulting velocity V is the combined effect of W_2 and the rotational velocity U_2. From a comparison of these two figures it is evident that a fan with longer blades, if they are both straight, will give a greater pressure than may be obtained from a short-bladed fan at the same speed.

By curving these short blades either forward or backward, as in Fig. 8, any desired variation in velocity may be obtained for the air leaving the tip of the blade. Thus when the blade is bent forward, a pressure greater than that corresponding to the peripheral velocity will be obtained. This results in the same pressure at a lower speed than would be necessary with a straight blade and the same wheel diameter. In case it is desired to directly connect a fan to a high-speed unit without developing the corresponding high velocity, the blade may be bent backward.

Centrifugal fans may be divided roughly into two classes, those with straight radial blades and those with blades curved with reference to their direction of rotation. The amount of total pressure developed by a straight-blade fan may be mathematically determined, but in the case of a curved-blade fan this can be known only by actual test.

An essential feature is the housing in which the wheel or rotor is inclosed. The kinetic energy of the air leaving the periphery of the wheel to a great extent must be converted into potential energy in the form of static pressure before being serviceable. This conversion from kinetic energy or velocity into static pressure is ordinarily accomplished in the scroll formation of the fan housing. A still further conversion is often secured, where the velocity leaving the outlet is high, by means of a diverging nozzle at the outlet. The shorter the blade the greater must be dependence on the scroll-shaped housing to obtain the desired static pressure, and for this reason a properly designed housing is of more importance with a multivane fan than with the older straight-blade type.

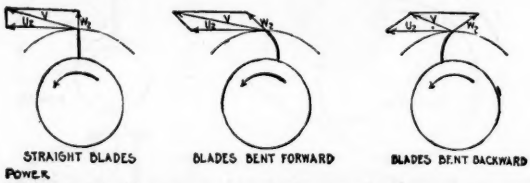


FIG. 8.—RELATIVE EFFECT OF DIFFERENT-SHAPED BLADES.

The standard steel-plate fan may be considered as a specimen of the straight-blade type, although if the tip of the blade is bent in either direction the characteristics will be slightly changed. The ordinary steel-plate fan does not give as high an efficiency as the multivane type, because it is designed for a large capacity rather than for high efficiency. But if these straight-blade fans are made long and narrow, with a smaller inlet than is used on the standard fan, they may be made to give higher efficiencies than can be obtained from any of the multivane type of fans.

The size of inlet depends on the cubic feet of air handled per revolution of the fan, and there is a certain diameter of inlet that will give maximum economy. The smaller the inlet diameter as compared to that of the wheel, the greater will be the efficiency obtained, but at a sacrifice in capacity.

RELATION BETWEEN STATIC, VELOCITY AND TOTAL PRESSURES AND BETWEEN STATIC AND TOTAL EFFICIENCY.

Frequent reference has been made to static and velocity pressures, and also to the conversion from velocity pressure, to static pressure at the fan outlet. In practically all installations using centrifugal fans there exists a certain static resistance of the system to be overcome. One common source of such resistance is the loss by friction due to transmitting the air through the system of ducts, which varies with the roughness of the surface, the resistance of elbows or other obstructions, and as the square of the air velocity. A further source is in the fuel bed of furnaces or the grates of a boiler; the resistance offered by the boiler itself or by an economizer in the case of an induced-draft fan; the loss in head at the hoods and through the collector in an exhaust system; and the resistance of the heating coils or air washer in a heating or ventilating installation.

It is necessary for the fan to develop a definite static pressure sufficient to overcome the various static resistances of the system. In addition to the static pressure, the air has imparted to it a certain velocity pressure due to its velocity on leaving the fan outlet. This velocity is dependent on the amount of air handled and on the area of the fan outlet.

The total pressure is the velocity pressure at the fan outlet plus the static pressure of the system, and is the pressure upon which the performance and efficiency are usually based. In the case of an exhaust or "draw-through"

system, the static head should be taken as the difference in static pressure at the inlet and outlet of the fan, one being positive and the other negative.

The relation between static and total pressure and between static and total efficiency is not generally understood. Many consider only the total efficiency, even when the resistances are estimated in static pressures. The static pressure is the potential energy developed by the fan, and is the energy available for performing useful work in overcoming the frictional resistance of the system. The velocity pressure is the kinetic energy used in moving the air and is a measure of the air quantity handled, but until it is converted to static pressure it is not available for overcoming resistance.

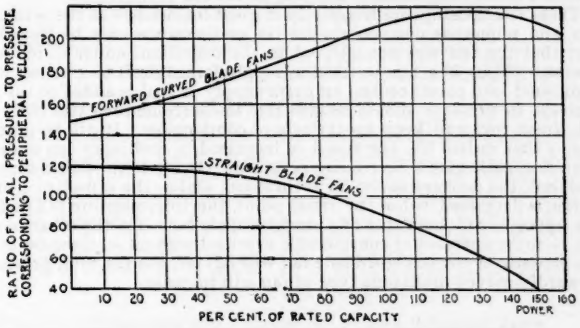


FIG. 9.—PRESSURE CHARACTERISTICS AT CONSTANT SPEEDS.

Thus it is seen that the greater the static pressure developed at the fan outlet in proportion to the velocity pressure, the more effective will be the performance of the fan in overcoming frictional resistance, and therefore the greater the "static efficiency." The efficiency is the ratio of the power output to the power input, or the ratio of work done in delivering a certain amount of air against some known pressure to the work done by the engine or motor used in driving the fan. There may be two different efficiencies, static or total, depending on whether static or total pressures are considered. Since the total pressure is greater than the static, the total efficiency is greater than the static efficiency, and for this reason the efficiency generally referred to in fan performance is based on the total pressure.

A fan having a high total but a low static efficiency may be less desirable than another having a high static efficiency but relatively lower total efficiency. The static efficiency may be readily calculated when the ratio of static to total pressure at the rated capacity of a fan is known. Thus, if the static pressure is 80 per cent. of the rated total pressure, the static efficiency will be 80 per cent. of the total efficiency.

The efficiency, in terms of either the static or total pressure, may be calculated by means of the following formulas:

$$\textit{static efficiency} = \frac{0.0001565 \times Q \times \textit{static press. (inches)}}{\textit{horsepower input}},$$

$$\textit{total efficiency} = \frac{0.0001565 \times Q \times \textit{total press. (inches)}}{\textit{horsepower input}},$$

where Q equals the quantity of air in cubic feet per minute.

RELATIVE PRESSURE CHARACTERISTICS OF STEEL-PLATE AND MULTIVANE FANS.

As may be seen from Fig. 9, the pressure characteristics of a fan having forwardly-curved blades are quite different from one having straight blades. This is not generally understood and is often overlooked in the selection of a fan for any specific duty. It will be noted from the curves that when a fan with forwardly-curved blades is operated at constant speed and at less than the rated capacity corresponding to that speed, the total pressure developed will be less than the rated pressure at rated capacity. Given this same condition with a straight-blade fan, operating at constant speed, the pressure tends to increase as the load on the fan is reduced.

These relationships are frequently of great importance in the selection of a fan, and numerous disappointments in performance may be traced to the fact that the fan was not adapted to the conditions under which it was to operate. Thus if a fan be used to supply forced draft to a boiler, when an additional load comes on and an extra supply of coal is added to the fire, an increase in pressure should be available to overcome the extra resistance of this fresh fuel and keep up the rate of combustion. It will be noted from Fig. 9 that unless the fan speed is increased, a multivane fan under these conditions will give a decreasing pressure. Owing to the thickening of the fuel bed, the delivery of the air is throttled, and as the capacity of this type of fan is decreased below the rated point, the total pressure falls off. Just the opposite will hold true of a straight-blade fan. On the other hand, if a fan is to be operated at considerable overload without an increase in speed, the pressure of the straight-blade fan will fall off, but the total pressure of a forwardly-curved multivane type of fan will increase.

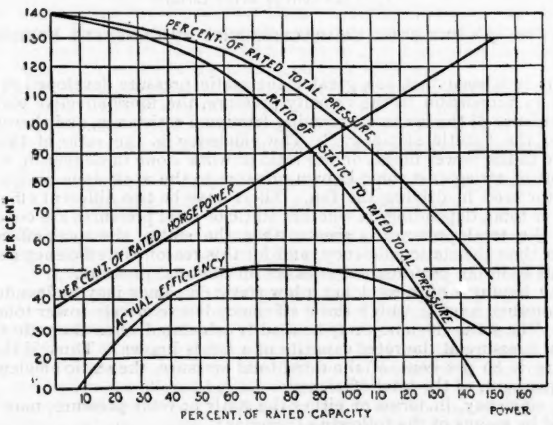


FIG. 10.—PERFORMANCE CURVES OF STRAIGHT-BLADE TYPE.

A better conception of the relative performance of the two types may be had from a comparison of the diagrams in Figs. 10 and 11. The curves in Fig. 10 show the relative performance of a straight-blade steel-plate blower of standard make, and gives the performance at other than the rated capacity. The horsepower characteristics for this type give a straight line. According to the curve, the rated total efficiency for this fan is 50 per cent.

The curves in Fig. 11 show the relative performance of a well-known fan of the forwardly-curved-blade multivane type. If this fan is operated at 50 per cent. of the rated capacity but at rated speed, the static pressure will be about 83 per cent. only of the rated, and there will be a drop in static efficiency of approximately 10 per cent. One advantage of this type may be noted from Fig. 11, where it will be seen that the static-pressure curve is compar-

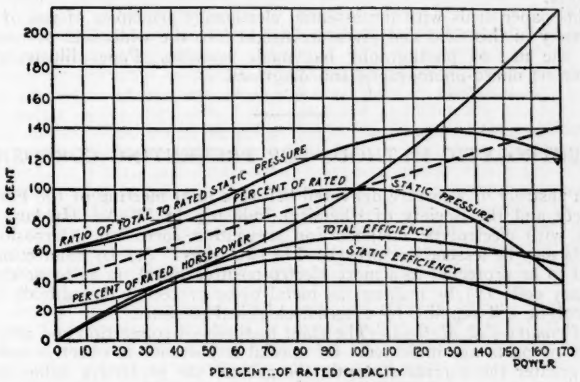


FIG. 11.—PERFORMANCE CURVES OF CURVED-BLADE TYPE.

atively flat at the point of rating, and that a considerable range of capacity may be obtained without serious loss in efficiency. Also, as seen from the horsepower curve beyond the point of rating, the power consumption goes up very rapidly, with an increasing total pressure. This explains why this type, when motor-driven, is so likely to overload the motor and why care should be taken to specify a motor sufficiently large if there is any possibility of an excessive overload.

CONCLUSIONS.

From the foregoing it will be seen that different types of fans have widely different characteristics, and should be intelligently chosen if the best results are to be expected. While the impression seems quite general among engineers that the multivane fan is inherently more efficient than the steel-plate type, this is true only of the commercial steel-plate fans as ordinarily placed on the market. These fans are designed for large capacity rather than for high efficiency, but if properly designed, a straight-blade steel-plate fan may be made to give even higher efficiencies than multivane fans. This calls for a tall, narrow fan.

The multivane fan is of special advantage where space (more particularly head room) is of importance. Its higher speeds are also an advantage, since they allow direct connection to higher-speed motors, or give better pulley ratios where the fan is belt driven. Where a constant or increasing pressure is required when operating at less than the rated capacity, the straight-blade fan should be used, but the multivane type is the better one to use where a constant or increasing pressure is required above capacity.—"Power."

METALS.

PHOTOGRAPHY AND THE TESTING OF MATERIALS, by Prof. W. E. DALBY, F. R. S., M. Inst. C. E.—Paper read before Section G of the British Association in Australia, August, 1914. Reprinted in "Engineering," August 28, 1914.

This paper deals with the essential elementary principles of use of photography in this field and gives an insight into the wide field of research that the use of photography has made possible. Paper illustrated by numerous micro-photographs and diagrams.

ELECTROLYTIC METHODS FOR PREVENTING CORROSION.

An abstract of a lecture delivered before a joint meeting of the Faraday Society and the Society of Chemical Industry, by W. W. Haldane Gee, deals with electrolytic methods for preventing corrosion. Corrosion of metals may be lessened or prevented in two ways: (1) By connecting the metal to be protected to a more electro-positive metal, so as to produce a primary cell; (2) by making the metal to be protected the cathode in an electrolytic cell supplied by external electrical pressure.

1. *Primary-Cell Method.*—The chief methods of connection and arrangements of parts are indicated. Of special importance is effective voltage. The greater the current strength, the greater the protective value of the cathode from corrosion. When hydrogen is formed at the cathode, the pressure or over voltage necessary to liberate the gas may be important. Thus zinc is a good protector for brass, the over voltage being small and the current large; it is a poor protector for tin, the over voltage for tin being especially high. The prevention of corrosion of a metal by direct application to it of a more electro-positive metal was suggested by Sir H. Davy. His experiments on the protection from corrosion of the copper sheathing of ships, detailed in the "Transactions of the Royal Society," showed that a relatively small area of iron or zinc would protect copper; the method had to be abandoned owing to the clean copper forming a surface on which shellfish and seaweed flourished, making the bottoms very foul. Diegel, in 1898, confirmed Davy's results that both zinc and iron would act as protectors of copper and brass. E. Cohen, in 1902, showed that the method might be used with advantage by marine engineers for the protection of condenser tubes, etc.

More recently, Engineer Rear Admiral Corner has detailed cases where the presence of iron strongly counteracts the corrosion of copper and brass. Iron is more efficient than zinc, owing to the possibility of maintaining a better metallic contact.

Protectors made of aluminum and aluminum alloys are used in some systems. Although aluminum is a very electro-positive metal, some precautions must be taken in its use. Thus, in sodium-chloride solution it is electro-negative to zinc, and the latter metal corrodes. At 70 degrees C. the potential difference changes and aluminum dissolves; on cooling, the reverse change takes place.

The use of zinc for the protection of steam boilers has been in practice for about eighty years. There are results of experience which show that if used in sufficient quantity, and properly applied and connected, the protection afforded is perfect. It is advised to use 1 square foot of zinc to 50 to 100 square feet boiler surface. H.M.S. *Crocodile* is said to have used 425 to 630 pounds rolled zinc per boiler per annum. A case is mentioned where slabs of zinc 12 × 12 × 1½ inches disappeared in six weeks.

2. *Use of External Electrical Pressure.*—Now that the supply of cheap electrical energy is so general, the use of an external pressure for protection against corrosion deserves careful attention.

Experiments made at the Manchester School of Technology show that quite a low value of current density is sufficient for adequate protection. This current may be calculated from the loss due to corrosion, in accordance with Faraday's law. In a case in which the loss of iron in sea water was equivalent to about 0.004 ampère per square foot, the application of this current density gave protection. In another case, in which 1/5th to 1/1000th normal sulphuric acid was used, current densities of 0.144 to 0.072 ampère per square foot proved sufficient. The Cumberland process of electrolytic protection is described, and its manner of application indicated. Anodes of carbon or iron are used, and continuity of electrical supply by both dynamo and storage cells. Rhoestats and ammeter are provided, so that the current density may be controlled. The results of the application of this system to many marine and land boilers have been satisfactory. The patents of Harris and Anderson are devoted mainly to the protection of surface-condenser tubes. They have shown that a minimum current density of 0.0012 ampère per square foot is sufficient for protection. In the case of a certain condenser of 1,025 square feet area, 2 ampères at 2 volts is continuously supplied. This represents an annual expenditure of energy equal to 35 Board of Trade units. Other applications of the method are described.

Commercial success demands that: (*a*) The current density should be sufficient, and equally distributed by a sufficient number of anodes; (*b*) anodes and electrical connections should be well insulated; (*c*) the nature of the anodes should be rightly selected; in some cases they may be soluble, in others they must be insoluble.—"The Steamship."

TYPICAL FAULTS IN STEEL CASTINGS.

In comparison with cast-iron founding the manufacture of steel castings can well be considered difficult. Many obstacles are met with, the overcoming of which needs wide experience. The chances of failure are also very much greater, and even with the greatest of care and skill the percentage of loss will be heavy, and also seemingly faultless castings sometimes will show defects during the machining.

The principal faults of steel castings are: (1) Short-pouring so that the mold is not completely filled with metal, or so that wrinkles and misruns show on the surface of the casting. (2) The breaking off of parts of the mold and the lodging of such dirt on the upper surface. (3) Internal stresses, causing cracks during cooling of the casting. (4) Gas and air blows. (5) Hollow spots or "pipes," caused by the shrinkage of the metal while passing from the fluid to solid state. (6) Cooling or shrinkage cracks.

The first of the above-named faults is a natural consequence of the high melting point of the steel, and the difficulty of heating it to a sufficiently high point. It is, therefore, not possible to cast steel very thin in the same way as cast iron, especially if the thin surfaces are large. Smaller castings can, however, be made of a thickness of only 3/32 inch or 1/8 inch. But to cast large, thin surfaces of steel is very difficult, even if the metal is so hot and seems to run so easy that even the very smallest details will come out perfect. This feature seems to be caused by the way in which the cooling of steel takes place—*i. e.*, quicker than cast iron and over larger

parts at the same time. It is, therefore, very important to fill the molds as quickly as possible. The gates should be large and the taphole in the bottom-pouring ladle ample.

The surface of a steel casting sometimes shows wrinkles or folds of the metal seemingly caused by it not having run freely, and usually by the molders classified as "short runs." This fault is probably caused by dampness in the mold, not seldom absorbed after the drying, as the fact that the "wringles" more often appear on the thick parts of the casting than on the thinner should indicate that the metal is not at fault.

The breaking loose of parts of the mold is caused by it not having been dried well enough or by large surfaces or sharp corners not having been strengthened sufficiently. The loosened dirt will lodge on the upper surfaces of the casting, and it is, therefore, best to provide ample metal for finishing and to cast downwards the surfaces which are to be machined.

The matter of internal stresses has been discussed above, and if specially sensitive castings are handled with some care before the annealing, no cracked castings should result from that cause.

Gas-blows are generally a consequence of too low silicon in the bath. In acid metal this is rarely the case, but in basic it might occur that too much of the Si will go into the slag, so that the remainder will not suffice to hold the gases dissolved; they will then separate out during the cooling of the steel, and the castings will be full of blowholes lying close to each other. It might happen that the metal is so full of gas that risers and gates will have convex upper surfaces and the volume of the metal increase instead of shrink; if this is noticed such metal has to be thrown out, as it is not fit to be used. Blowholes can also be caused by the mold not being fully dry. In such cases the holes will be small, of a diameter of 1/32 inch, close to each other, and have a depth of almost ½ inch; they will lie close to the surface, and will show after the outer skin has come off through the annealing. If the air and gas in the mold cannot escape during the time the metal fills the mold, blowholes will follow. They will be comparatively large, flat, and situated on the highest surfaces in the mold. Such blowholes stop at a distance under the surface, and can, therefore, not be noticed until the casting is being machined. By taking care that the venting of the mold is good, through the use of suitable molding materials, blowholes of this nature can be avoided. It is always safe, however, to provide steel castings with ample metal for finishing.

The faults which probably are most difficult to overcome are those mentioned under (5) and (6) above—namely, "pipes" and cracks. The former are caused by the shrinking of the metal while cooling. This begins along the walls of the mold, and from the surfaces proceeds inwards. The decreasing of the volume caused by the shrinkage is counteracted by drawing metal from the parts which still remain fluid, and this action naturally passes from the inner parts towards the outer, so that finally in the center an empty space or "pipe" is left. As seen, the pipes must form, unless means are provided to prevent them, as by applying risers or feeding heads on the castings and in such places that the decreases in volume are supplied with metal, whereby the final pipe will lodge in the riser and leave the casting dense. The correct placing and suitable dimensioning of risers and feeding heads is one of the very important demands which the skilled steel founder has to meet. The metal in the risers is so much waste, and it is important that they be made no larger than necessary. To get the pipe to lodge in the riser this must cool last, and it should, therefore, be placed so that the cooling will go in the direction towards the riser and not from it. As a rule, those parts of the casting which are larger than the surrounding ones must be provided with risers, and it should be plain that the thickness of these must be even, so that the metal has no chance to cool in them before in the casting.

Sometimes it is impossible to place ordinary feeding heads on parts where they are needed, and it may then be necessary to add to the thickness of the casting or even provide additions to certain parts to supply metal to draw from, such added additions being machined off later. As an example might be mentioned a roll, where, if the roll is cast on end, the application of a riser on the heaviest or center part is not possible. If no feeder is provided pipe will occur in the center of the heavy part, and the casting will be more or less unsafe. If, in order to overcome the pipe, the upper and smaller end of the roll casting is extended so as to form a feeding head, the pipe will still occur, because the last cooling will not take place there, but in the heavy center. It is, therefore, necessary to cast the roll with the same diameter all the way up to the top, and extend it upward to form the required feeder. Many other examples could be mentioned where it might be necessary to make large extensions or changes in the form of the original pattern in order to get the required feeding of the shrinkage, but what has been said should be sufficient to show the importance of care and judgment in the proper feeding of shrinkage.

The volume contraction or internal shrinkage of steel while cooling is not constant, but varies to a certain extent, depending upon the composition of the metal as well as the temperature. Metallurgists do not fully agree as to the causes of the difference in such shrinkage, but it is supposed that higher silicon and higher temperature will increase it; as a rule, it amounts to from 5 to 6 per cent.

The relation between the weight of the feeding head and that of the finished casting also varies considerably, so that it sometimes can be as low as 15 or 20 per cent.; but then again it can often run up to 100 per cent., while the average in most steel foundries is rarely much below 50 per cent. It is economical to keep the weight of this scrap as low as possible, but the form and construction of the piece will determine how large the risers must be. In arranging for the cooling to proceed towards the riser, the gates must be placed so that the steel will cool last here. The most radical way to gain this result would, of course, be to let the metal enter in the upper part of the mold; but this can rarely be done, because of the risk of pieces breaking out in the mold then is greater. It is therefore, customary to cast from the bottom, and in order to avoid the coldest metal coming in the riser, the metal is poured through the gates only until the mold is filled up to the bottom of the riser, and then hot steel is poured directly in this. In placing the gates for very deep molds it is well to use a few intermediate gates at different levels, so that the steel which is rising in the mold will be livened by hotter metal entering through the higher gates. The use of artificial means, such as Thermit, to keep the metal fluid and hot, the writer does not believe to be anything but half measures at the best, and it is better to have everything so well provided for that such addition can be avoided.

The last of the above-mentioned common faults in steel castings is cracking, of which there are two distinct classes—viz: that caused only by the contraction of the metal while cooling, and that which is consequent on internal shrinking. The contraction of steel castings is usually figured at 1.8 to 2.0 per cent., for which additions have to be made on the patterns. It must be remembered, however, that, like the shrinkage, the contraction is not constant, and can be different even in different parts of the same casting, depending upon the form of the piece as well as upon the elasticity of the mold. The contraction will, for instance, be larger if the casting is uncovered immediately after pouring than if it is left to cool in the covered mold. Contraction cracks will usually appear in thinner parts, and must frequently be remedied through welding.

Cracks caused by the shrinkage of the steel mostly occur in corners, close to ribs, and changes in thickness of the casting, etc., and are often very

troublesome. The metal will in such places keep fluid longer than on straight parts, and the feeding will therefore go from them, leaving the casting weaker, so that the resistance to contraction stresses is lessened and cracks result. Such cracks sometimes have the character of an extended pipe rather than of a regular crack. To overcome cracks of this kind recourse must be had to the regulation of the cooling, judicious placing of the gates, and the application of strengthening ribs. Some foundrymen try to overcome the difficulty by uncovering the casting as quickly as possible after it is cast, but this can hardly be an effective way, because the cracks occur at the moment the metal passes from the fluid to the solid state, and it is naturally impossible to have the casting uncovered so soon. Only experience can provide the right use of the means available to avoid them, and in this connection only a general idea of how they can be employed can be given. The cooling is regulated by placing a number of nails very close to each other at the points where cracking is feared, or by the application there of chilling plates, etc., all in order to hasten the cooling there, and thus make it more even over the whole casting.

In cutting the gates it should be borne in mind that the hot metal must be kept away from the points where the cracks are liable to appear; in casting, for instance, a flange with a horizontal and a vertical part, the gate should be cut on the top and not on the circumference of the horizontal part, where the cracks naturally would be. Strengthening ribs are cut at right angle with the line on which the cracks are to be feared; they should be thin, so that they cool quickly and thus help to resist the strain during the contraction.

In spite of all care, it seems sometimes to be impossible to avoid cracking, and the only way then is to change the construction of the piece, so that the dangerous points can be avoided.

Strength of Cast Steel.—Steel castings can be made with carbon at almost any figure from 0.10 to 1.50 per cent., and with different characteristics. Open-hearth metal for casting purposes is, however, usually made in three grades of hardness; very soft steel with a tensile strength of about 55,000 pounds per square inch, suitable for electrical purposes; medium hard, used for average machine castings, and with a strength of from 62,000 to 72,000 pounds per square inch; and hard steel for parts which must have resistance against wear, etc., and with a strength of from 96,000 to 125,000 pounds per square inch.

A very important quality which should be looked for in steel castings is resistance to shock and heavy blows. As a rule the castings are not tested with a view to ascertaining this quality as often as should be the case, so that no figures can here be given to show common results in this respect. In breaking up steel castings it can be noticed, however, that frequently the strength compares favorably with forgings, so that they will stand considerable bending and a good many blows before breaking. Castings, nevertheless, are not suited to indiscriminately replace forgings, although several attempts have been made to make such pieces as crankshafts, shafts for engines and pistons, etc., from castings. The main reason for the superiority of the forged material for such purposes is reliability, as one can never be absolutely certain of the density and freedom from gas blows and pipes in the case of castings. On the other hand, the castings are much to be preferred for such constructions which cannot be forged in one piece, as, for instance, stern frames for vessels, rudder frames, locomotive driving wheels, etc., where welding otherwise would be involved.—"Foundry Trade Journal."

INFLUENCE OF VARIOUS TEMPERATURES ON THE PROPERTIES OF ADMIRALTY GUN METAL.

By Prof. John G. Longbottom, A. R. C. S., M. I. Mech. E., and Prof. A. Campion, F. I. C., F. C. S.

In their paper read before the Institution of Engineers and Shipbuilders in Scotland, at Newcastle, the authors said that the earliest published results of experiments on the effect of temperature on the mechanical properties of gun metal appear to be those contained in a report of investigations on alloys carried out under the direction of the Admiralty at Portsmouth Dockyard in 1877. Heating of the test bars was effected by means of an oil bath, from which they were transferred to the testing machine, and broken with as little delay as possible. At the best the results can only be considered as roughly approximate, owing to the variable and uncertain cooling of the specimens during testing.

Two series of gun-metal bars of the same composition were tested in tension. In the first series the tensile strength fell from 12.0 tons per square inch at atmospheric temperature to 11.2 tons per square inch at 300 degrees F. (148.9 C.), while in the second series the fall was from 12.9 to 6.6 tons per square inch. The corresponding changes of ductility were from 12.5 to 10 in the first series, and from 8.75 to 0.66 in the second series. Great changes in both tenacity and ductility were found in the first series at temperatures from 350 degrees F. (176.7 C.) to 400 degrees F. (204.5 C.) the strength falling from 10.1 to 5.5 tons per square inch, and the ductility from 8.25 to 0.75.

The authors next enter in their paper upon a long and detailed account with illustrations of the various tests and apparatus employed by them in the course of their researches. For lack of space we are obliged to omit this matter and pass on to an abbreviated account of their deductions.

In testing not only non-ferrous metals, but also steels, at some temperatures, very marked slips occur after the yield point is passed; in some cases these slips are so great that the steelyard of the machine falls on to the bottom stop as if rupture of the specimen has occurred; but after a short time the material stiffens, and carries a further load. A series of such slips, in some cases as many as ten, have been observed between the yield point and the maximum stress of the material. If the load be reduced when one of these slips has taken place, so as to allow the steelyard to rise, it is found that the load may be increased a little beyond that at which the slip occurred before the material again slips. These slips are invariably accompanied by an evolution of heat.

These phenomena were not observed in tests of this material at temperatures above 350 C. They are generally more marked in rolled than in cast material.

In the opinion of the authors this is due to the amorphous cement recrystallizing to such an extent that the adhesion between the crystals of the metal is reduced sufficiently to allow some of the crystals to part from their neighbors under the particular stress. Actual fracture is, however, prevented by the crystal faces rubbing one against the other with considerable pressure, thus reforming a quantity of the amorphous material, with the result that adhesion is partly restored. This material is in turn recrystallized under the influence of heat, and another slip takes place. In this manner there is alternately destruction and restoration of the amorphous material, with corresponding alternate decrease and increase of strength of the material.

Evidence in support of the author's view was obtained in a somewhat unexpected manner. It had been noticed on several occasions during the progress of a test that the temperature suddenly rose several degrees, which in the earlier experiments was attributed to changes of voltage in

the heating current. It was, however, observed during the testing of some steels that this sudden increase in temperature always occurred soon after the elastic limit had been passed. This led the authors to make very close observations during the later tests on the gun metal, which resulted in the interesting discovery that immediately after each of the slips mentioned above an appreciable increase of temperature of the material occurred. So far as the authors are aware, this has never before been recorded, although it is what might be expected to result from the recrystallization of the amorphous material.

Ewen and others have shown that plastic deformation of crystalline metals takes place partly by the crystals slipping one over the other, and partly by deformation of the crystal elements themselves.

The crystalline structure of metals has been likened by Rosenhain to a pile of bricks stacked in a regular manner. If this analogy be carried a little further, by considering that each brick, instead of being rigid, is composed of a substance like indiarubber, and that the joints between them are filled with a cement, which itself is stronger than the material of the crystals or bricks, it may be used to illustrate the behavior of metals at high temperatures. As long as the cement retains its strength the application of stress produces deformation, principally by an alteration in shape of the individual crystals; fracture ultimately takes place by a tearing of a portion of the material in contact with the cement, and the material has considerable ductility. If, however, the strength of the cement becomes impaired, the applied stress produces a smaller amount of deformation in the crystals themselves, more slip between the joints, and the ductility of the material is reduced. When the cement is weaker than the material of which the crystals are composed, there is practically no deformation of the crystals, and fracture, which takes place when the ultimate strength of the cement is reached, is due almost entirely to slipping.

The authors consider that the amorphous cement loses its ductility at a lower temperature than at which it loses its strength, and consequently the ductility of the material deteriorates more rapidly than the strength with increasing temperature. The roughened appearance of the surface of the specimen after testing at the lower temperatures, in contradistinction to those tested at high temperatures, lends additional support to these views.

This theory seems to the authors to furnish a complete explanation of the critical points in the ductility curves at 350 degrees C., and of the entire mechanism of failure of the material at various temperatures.

In this research no special precautions have been taken to avoid oxidation, as it was their desire to test the material under, as nearly as possible, the conditions to which it would be subject in practice; but they are thoroughly alive to the fact that oxidation may have an important influence on the behavior of the material at temperatures above that of the atmosphere. It is their intention to make further experiments in a non-oxidizing atmosphere.—"Page's Weekly."

BABBITT AND ITS APPLICATION.

By T. J. Johnston.

Each degree of frictional heat that is developed in a machine bearing is a measure of just so much useful power entirely thrown away, in that each degree of heat shown in the bearing above that of the atmosphere represents just so much heat removed from beneath the boiler, which, instead of doing useful work, only produces so much additional waste

in the machine. It is therefore very essential that machine bearings be as nearly perfect as it is possible to make them.

In order that a bearing may run cool, careful attention must be given to several important items; the proper materials must be selected for the journal and bearing, the wearing surfaces must be perfectly smooth, and of sufficient area and uniform bearing surface. These surfaces must, moreover, be furnished with properly-placed oil grooves which will distribute a lubricant evenly to every portion. A constant supply of lubricant of sufficient quantity and proper quality must also be provided, and dust, dirt and all other foreign matter must be rigidly excluded As a matter of course the mechanical design of the bearing must be right, but the selection of the proper bearing materials and the proper application of those materials are matters of first importance.

A good bearing material must fulfil the following requirements: It must be of sufficient strength to sustain its load; it must not heat rapidly; it must be easily worked; it must have good anti-frictional properties; it must have a long life with small loss of material due to wear; and (with the exception of cast iron on cast iron and hardened steel on hardened steel) it will usually be a material of an entirely different molecular construction from that of the revolving journal which it must support.

Chief among the materials which are used in the construction of bearings are: Cast iron, steel, gunmetal, phosphor bronze, and white alloys. Numerous other materials, many of which are patented, have also been used for bearings with more or less success. Some of these latter are tempered copper, coiled steel wire, aluminum, lignum-vitæ, and other hard woods, compressed paper, stone and glass compositions.

The white-metal alloys are solid materials composed of two or more items, such as aluminum, zinc, nickel, tin, lead, copper, antimony and bismuth, in varying quantities and fluxed and alloyed in various ways.

The journal when running may be completely borne by the oil film, but during the time of starting or stopping the film is broken, minute irregularities on the surfaces of the bearing and journal engage, and if the bearing does not yield, as in the case of a steel bearing and a steel journal, small particles are fused and torn out, and these accumulate at the entrance point, and may cut both the bearing and the journal.

With a steel journal running in a white-metal bearing, the bearing surface is entirely different in its molecular structure, the bearing inequalities are not strong enough to resist the minute inequalities in the journal, and so, instead of fusing, they yield and are smoothed out. Consequently, the bearing surface, instead of being injured by contact and momentary high coefficient of friction, is smoothed and burnished, thus preparing the way for a uniform wedge oil film with a minimum coefficient of running friction.

White-metal alloys have other advantages to recommend them for bearings besides their anti-frictional properties. They are very easily worked, and can be melted in an ordinary iron ladle, so that no special equipment is required for the replacement of worn bearings; they are very long wearing, and show but little loss of material due to wear even after long service; they tend to reduce shock on machines as well as to deaden noise; and they can be very readily provided with grooves for lubrication, and are very easily fitted to a uniform bearing.

A fault to which all white-metal alloys are heir is their liability to melt and run from the bearing shell should accidental overheating take place. It is to be remembered, however, that although other materials do not melt and flow when overheated, an equal amount of heating will cause equally disastrous results to their properties as bearing materials.

All of the white-metal alloys which are used in the construction of bearings are somewhat erroneously called babbitt metal. In 1839 a patent was granted to Isaac Babbitt for a special type of bearing enclosing a

soft-metal alloy. The features of this bearing were lips extending around the ends of the soft metal to retain it in case of accidental heating and to prevent the soft-metal lining from being crushed or spread out under severe pressure. The alloy which Babbitt used in his bearing was probably composed of tin 24 pounds, antimony 8 pounds, and copper 4 pounds, to each of which was subsequently added 2 pounds more tin. This gives a metal composed of 88.88 per cent. tin, 7.4 per cent. antimony, and 3.7 per cent. copper. Metals of this type, which approximate 90 per cent. of tin in their composition, are now called U. S. Government Standard or A1 babbitt, and all other white-metal alloys on the market for use in bearings, no matter what their composition, are called babbitt.

Genuine babbitt, when properly made, has a low melting point, is easily worked, has good anti-frictional qualities and will stand a large amount of careless handling, but the constantly increasing cost of tin has made it necessary to secure a good babbitt with a cheaper metal as a base. Laboratory tests show that a lead-base babbitt will give very good results, but such tests of bearing materials are difficult and uncertain and apt to be misleading. Similarly, chemical tests cannot be wholly relied upon, since a very great deal is dependent on the actual making of the babbitt. But laboratory and chemical tests taken in conjunction with actual service tests furnish very reliable data, and a bearing metal developed along these lines may be counted upon to give consistent results in practical work.

Babbitts made up according to nearly 300 different formulæ are at present on the market. It would be of very great benefit to the users of babbitt if this number were greatly reduced and the process of manufacture so standardized as to ensure a uniform quality of alloy. Except for a few cases, but two babbitts, one a lead-base alloy, the other a tin-base alloy, each being the best that can be made, are required for a complete line of bearings, ranging in weight from a few ounces to several tons. The best quality of high-grade metal should invariably be used.

Melting the Babbitt.—Babbitt used for bearings is melted in large iron pots or kettles and the molten metal kept at a constant temperature of about 465 degrees C. A constant temperature is of very great importance, and is most satisfactorily obtained by using a gas flame controlled by an accurate electric temperature regulator. The regulator is set to give a temperature variation of five degrees above and below the desired point, the gas being turned low when a temperature of 470 degrees C. is reached, and again turned on when the temperature falls to 460 degrees C.

The temperature should be brought up slowly and the babbitt thoroughly stirred, especially when new babbitt is being melted or when old babbitt which has been allowed to solidify in the pot is being remelted. This is necessary in order to prevent certain of the constituent metals from rising to the top and becoming oxidized, as well as to prevent the heavier metals from sinking to the bottom of the pot, thus producing a non-uniform alloy. There is very little probability of these difficulties being encountered after the proper working temperature has once been reached and as long as such temperature is maintained; but stirring at frequent intervals all through the process of working the babbitt is beneficial. In order to reduce oxidation the surface of the molten babbitt should be kept thoroughly covered with powdered charcoal or with graphite. Scraps of lead, solder or other metals or alloys should never be thrown into the babbitt pots, and any dross that may form on the surface should be removed at least once a day.

Bearing Shells.—Bearings are seldom made of solid babbitt, except in the case of small die-cast bearings, and in a few rare cases in railway work. Bearings made in die-casting machines are cast complete with oil grooves and oil-ring slots, and need but be reamed, faced and turned before being ready for insertion in the bearing housings. As a general

rule babbitt is used only as a lining in bearing shells of cast iron, malleable iron or bronze.

Cast iron is the most commonly used material for the bearing shells of all types of stationary machines on account of its strength, good working qualities and low cost. Where it is necessary to provide greater strength and toughness at moderate cost malleable iron is used. Cast steel is not a good material, owing to its tendency to warp when the casting strains are relieved, and also after babbitting. Bronze is used for bearing shells in railway work because its use makes certain the completion of a run, even though accidental heating results in melting the babbitt lining and causing it to run from the shell.

All cast and malleable-iron bearing shells are provided with cast anchor holes to hold the babbitt lining in place and to prevent its turning with the revolving journal. These anchor holes are made by attaching to the green-sand cores of the bearing-shell mold baked-sand anchor cores of such size that the anchor holes will be of the correct dimensions after the casting is machined. Bronze shells properly tinned require, as a usual thing, no other provision for holding the babbitt lining in place; but, in some cases, either anchor holes are drilled diagonally or undercut grooves are added to make doubly sure that the babbitt lining does not become loose. If anchor holes or grooves are used with bronze shells they should be few in number and as small as possible.

Iron bearing shells should be cleaned before babbitting, and all sand and scale removed by tumbling, sand-blasting or pickling in a hot soda ash solution or in muriatic acid. If necessary the sand should be loosened from the anchor holes by hand, for it is absolutely essential that no sand or grit remain to work its way into the babbitt lining. To assure uniformity in grain, wear and thickness of lining all bearing shells should be bored before babbitting.

Bronze bearing shells should be tinned by immersion in half-and-half solder before babbitting, great care being taken to secure a perfectly uniform clear film of tin over the entire surface to which the babbitt is to adhere; otherwise loose linings will result. The parts of the shell not to be tinned should be coated with a thin mixture of talcum water. Tinning on iron cannot be depended upon, since, at the temperature of molten solder, iron and solder do not alloy. Hence the coating will strip or peel when cold, while if the temperature is raised to that at which iron and solder do alloy, the solder will be oxidized and will not adhere to the iron.

All iron shells must be preheated to a temperature of from 100 to 150 degrees C. before pouring the babbitt. The higher temperature is, as a rule, the better to use, except where a lining is being poured in a very heavy shell, when it may be necessary to use the lower temperature to prevent the babbitt from cooling too slowly. Preheating should be done in an oven, but may be done over a gas or coke fire, in which case the surface to which the babbitt is to be applied should be turned upward, as otherwise a greasy deposit will be formed, which will prevent the babbitt from adhering properly to the surface of the shell and will cause loose linings. Bronze shells are usually poured as soon as they come from the tinning pot and while still hot from the tinning operation. The mandrels should be preheated to a temperature of from 100 degrees to 150 degrees when pouring babbitt into the shells, but for bronze shells a somewhat lower temperature should be used. After the first few bearings are poured it will become necessary to plunge the mandrels into water each time to reduce their temperature to the proper value. Oil holes in the bearing shells are filled with asbestos or wood driven against the mandrel, and the joints are made tight with clay.

Pouring the Babbitt.—Very careful attention should be given to the way in which the molten babbitt is poured into the bearing shell, since this is

perhaps the most important operation of all. To secure good results the babbitt must be poured at the correct temperature. If the babbitt is poured at too high a temperature extreme shrinkage will occur, resulting in porous areas in the lining and in broken anchors; furthermore, the babbitt will be oxidized, softened and dirty, and its anti-frictional qualities will be lowered. If the babbitt is poured at too low a temperature a lining having a coarse granular formation is the result. If the shells and mandrels are too cold, blowholes and similar defects will form, and the lining will shrink away from the shell in cooling. If the temperature of the shell or mandrel is too high the babbitt will cool too slowly, and the heavier metals will have time to settle, producing a bearing which will be soft at one place and brittle at another.

A ladle of the self-skimming type should be used, preferably one having a weld or riveted sheet-iron bridge to give the right size of stream for the bearing being poured, thus preventing splashing, as well as keeping dross from being poured in with the babbitt. An expert pourer of babbitt, with the use of an asbestos pad or a hand leather, grasps the handle of the ladle close to the bowl, and, standing almost perfectly rigid with his arms braced against his body, pours in a steady even stream without any splashing or surging of the metal in the ladle.

The best results are obtained by pouring the babbitt with the bearing shells in a vertical position. If it is impossible to place the bearing in a vertical position due to the irregular shape of the mandrel, it may be inclined and poured at the most convenient point. When split bearings are poured at an angle, care should be taken to place the shell so that the face is nearest the table. Split bearing shells are sometimes placed horizontally, with the convex side up over the mandrel on a surface plate, and the babbitt poured through holes left in the casting for the purpose. For very large bearings the shells are more conveniently placed concave side up and the ladle moved along the edge of the shell as the babbitt is poured.

Babbitt, especially the lead-base alloy, is weak while hot, and bearings must not be roughly handled or thrown about while the lining is cooling. If the bearings receive rough treatment before the babbitt is cool, anchors are liable to be broken off and the lining loosened.

Finishing.—The finishing of bearings is a well-known problem of ordinary machining and fitting which has been fully described and discussed elsewhere, and which need not be gone into in detail here. Metal fins and burrs are readily removed with an ordinary drawknife or spokeshave, or with a hot soldering iron. Lubrication holes are cleaned out with a hot iron, and all large bearings are thoroughly peened before machining. Oil holes are generally cut in the surface of the finished bearing by hand (except in die-cast bearings), because in most cases the babbitt lining is too thin to allow casting the grooves.

Repair Work.—The easy working qualities of babbitt make it especially suitable for repair jobs in the field. A good tin-base alloy, on account of its ability to stand more mistreatment than a lead-base alloy, should generally be used for this work. When no equipment is at hand and the cost of building a mandrel is prohibitive, or the time required to build it cannot be spared, successful work can be done with a mandrel of sheet iron. Paper may be used for bore allowances, asbestos cord to provide cast oil grooves, and clay and friction tape to seal up openings. It is even permissible in some cases to pour the babbitt into the properly prepared bearing shells with the journal in place, but the housing cover should be heated and clamped in position to heat up the housing and axle. All bearings should be poured at once, and great care taken, especially with small journals, to prevent springing.

The babbitt may be melted in the pouring ladle over an open fire, and the temperature assumed as right when a pine stick used for stirring

chars but does not ignite. The mandrel temperature is right when water evaporates rapidly from its surface without spluttering.

Summary.—The points to which attention must be given to babbitt bearings successfully are: Choose a good, properly blended alloy made from pure metals; melt it slowly, thoroughly and without overheating, and keep it at a constant temperature while working; have the surfaces of the shell dry and clean; warm them to the proper temperature, and if of bronze, tin them as well; have the mandrel correctly leveled, lined and centered, and likewise at the proper temperature; stir the metal thoroughly before pouring, and dip it from the bottom of the pot, pouring evenly and steadily without surging, splashing or pocketing air; machine, peen, scrape and fit the bearing accurately to the journal; and have oil holes open, oil grooves clear, and surfaces free from sand, dirt or babbitt chips. —"Electric Journal."

TURBINE MACHINERY.

THE DEVELOPMENT OF MECHANICAL GEARING FOR MARINE TURBINE MACHINERY.

By Ernest H. B. Anderson.*

Rapid progress continues to be made in the development and in the constructural details of mechanical gearing for ship propulsion. At the present time the total shaft horsepower of Parsons geared turbine machinery in vessels actually in service amounts to 62,500, and there is under construction an additional 650,000 shaft horsepower.

At present all merchant vessels in service fitted with this means of drive are operating in Great Britain and the Colonies, but there is being built in the United States 35,000 shaft horsepower of mechanical gearing, all of which is to be driven by Parsons turbine machinery installations for use in the United States navy or for the auxiliary vessels connected with the fleet. Among the vessels completed abroad the following may be mentioned, and full particulars of the machinery installation, trial-trip and service performances may be found in the proceedings of various technical societies or in engineering journals.

GEARED TURBINE INSTALLATIONS.

1. Steamship *Vespasian*, 1,000 shaft horsepower (Institution of Naval Architects, 1910 and 1911).
2. Steamships *Hantonia* and *Normannia*, 5,000 shaft horsepower (Institution of Naval Architects, 1912).
3. Steamship *Cairnross*, 1,700 shaft horsepower (North East Coast Institution of Engineers and Shipbuilders, 1913).
4. Steamships *Curzon*, *Hardinge* and *Elgin*, 2,500 shaft horsepower (Institution of Naval Architects, 1913).
5. Steamship *King Orry*, 8,000 shaft horsepower ("Engineering," June 27, 1913).
6. Steamship *Paris*, 14,000 shaft horsepower ("Engineering," December 5, 1913).
7. Two British destroyers.

The total number of vessels in the mercantile marine fitted and to be fitted with this system of propulsion is now in excess of forty. The Cunard Line has two large vessels for intermediate service in hand, the

*Member Institution of Naval Architects and Society of Naval Architects and Marine Engineers.

machinery of which will drive twin screws and each be capable of developing 10,000 shaft horsepower. John Brown & Company, Clydebank, has in hand a large vessel for the Orient Line which will have a machinery installation of 12,500 shaft horsepower. This vessel is being built for mail service between London and Australia, and direct comparisons can be made between the performance of the machinery with sister ships having twin-screw reciprocating engines and also one having a triple-screw combination arrangement of twin reciprocating engines working in conjunction with a low-pressure turbine. The Anchor Line has a large vessel under construction for passenger and freight business between Glasgow and New York. This vessel will be driven by twin screws, and the turbines and gearing are designed to develop 8,000 shaft horsepower under service conditions. Two vessels are under construction on the Clyde for the Canadian Pacific Railway Company, the machinery in each case being designed for 12,000 shaft horsepower, while the South Eastern and Chatham Railway Company has a high-power geared turbine vessel for mail service between Dover and Calais.

Among others may be mentioned the following:

One cargo boat of 3,600 shaft horsepower of the Brocklebank Line.

One cargo boat of 900 shaft horsepower of Ruys & Company, Holland.

Two vessels of 5,000 shaft horsepower of the Argentine Navigation Company.

Two vessels of 6,000 shaft horsepower of the Nippon Yusen Kaisha Company.

Five ocean-going vessels of the Federal Steam Navigation Company.

Two ocean-going vessels of the Austrian-Lloyd Company.

One ocean-going vessel of the Union Steamship Company, New Zealand.

One passenger steamboat of 2,000 shaft horsepower, building by A. & J. Inglis, and a lighthouse tender.

Fifty-eight war vessels of various types fitted with all-geared or part-geared turbine installations, two of which have all-geared turbine installations in excess of 30,000 shaft horsepower each.

GENERAL DESIGN.

The following illustrations show the general design of gearing under construction at the present time at the works of The Parsons Marine Steam Turbine Company, Ltd., Wallsend-on-Tyne:

Fig. 1 shows a finished gear wheel and pinion. The approximate diameter of the wheel is 132 inches, and the approximate diameter of the pinion 8 inches, the ratio of reduction being 16.50 to 1. On a vessel fitted with the standard arrangement, a similar pinion is arranged diametrically opposite, the high-pressure ahead turbine driving one pinion and a combined low-pressure ahead and astern turbine driving the other pinion, both pinions being in mesh with the gear wheel.

Fig. 4 shows the assembled turbines and gearing. The high-pressure ahead turbine with maneuvering valves is shown at the left bolted to the lower half of the cylinder casing. The combined low-pressure ahead and astern turbine are in one casing on the right. The condenser is placed under this turbine, the flange and bolt holes of the exhaust nozzle being clearly shown in the illustration.

The gears shown in these illustrations have been designed by Sir Charles A. Parsons, and the teeth have been cut on a hobbing machine, fitted with his latest invention, commonly referred to as the "creep" mechanism. Full details describing this invention and the experiments connected with its design were published in his paper on "Mechanical Gearing for the Propulsion of Ships" read before the Institution of Naval Architects, 1913, an abstract of which was published in "International Marine Engineering," June, 1913.

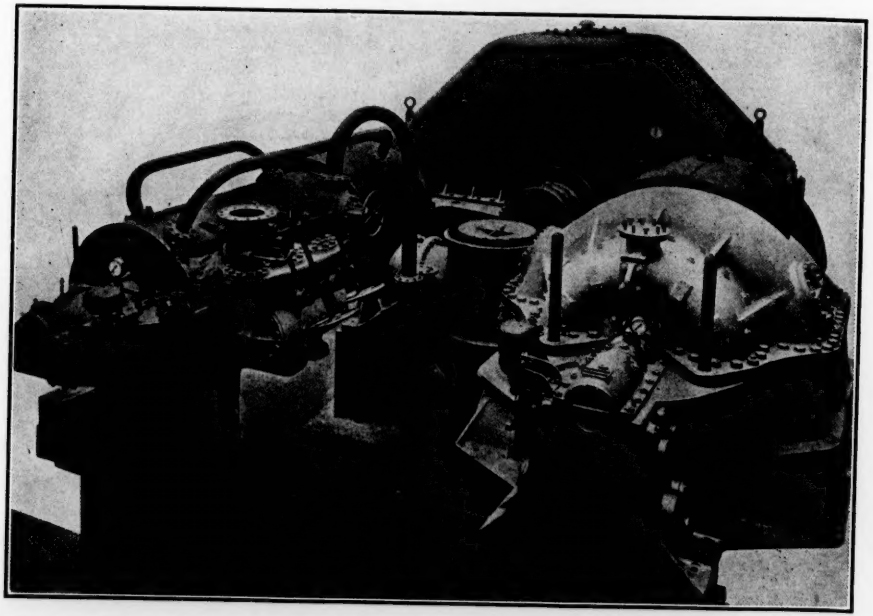


FIG. 4.—HIGH AND LOW-PRESSURE TURBINES AND REDUCTION GEAR ASSEMBLED. ASTERN TURBINE INCORPORATED WITH LOW-PRESSURE AHEAD TURBINE.

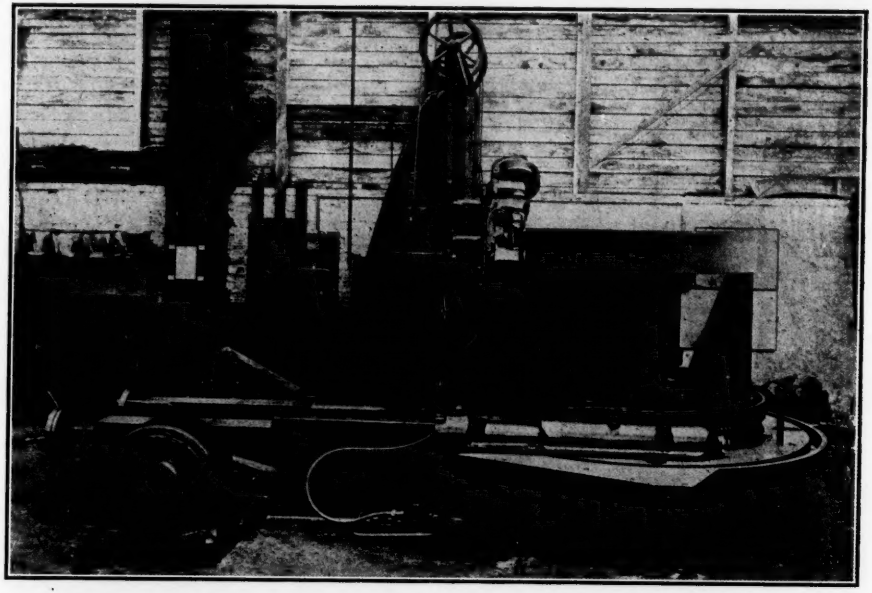


FIG. 5.—TYPE OF MACHINE ORDINARILY ADOPTED FOR CUTTING TEETH ON REDUCTION GEAR.

Careful tests and examinations have been made of gears which have been in operation for one or two years, and these tests have shown that the work has been distributed over the faces of the teeth fairly uniformly, and practically no wear can be detected in the teeth of either the gear wheel or pinions. In practice, however, experience has shown that the gears have been responsible for a certain amount of noise, although it has never been objectionable enough for passengers to make complaints, even in the boats on all-night routes, but it was evident that the art of cutting fast-running gears had not been perfected. Sir Charles A. Parsons and his colleagues realized that mechanical means would not entirely overcome this difficulty, and that the only true method to provide silent running gearing is in having a very high degree of accuracy in cutting the teeth.

GEAR-CUTTING MACHINE.

Fig. 5 shows an illustration of the type of machine ordinarily adopted for cutting the teeth, in which the work is mounted on a table rotated by means of a worm and worm wheel and to which the gear wheel is permanently attached during the process of cutting. This machine has been in use for upwards of three years, and upon which gear wheels have been cut amounting to a total of 100,000 horsepower.

The explanation for the noise produced in the gears cut on this machine was traced to the parent gear, and it was found to be due to very slight inaccuracies in the teeth, for which the worm and worm wheel drive were responsible. At the present time it is doubtful if a higher degree of accuracy in cutting can be relied on than in the case of this machine, unless by the introduction of multiple worms driving one worm wheel.

The means taken to overcome this difficulty are best described in Sir Charles A. Parsons' own words, quoted from the paper previously referred to:

"It will be seen that in the process ordinarily adopted, in which the work is mounted on a table rotated by means of a worm and worm wheel, the latter being attached permanently to the table, the errors will be some function of the angular position of the work, and, therefore, lie in planes through the axis of rotation; and if, as is mostly the case, the errors of the parent gear are periodic, these planes will lie at equal angular intervals, and will come into mesh periodically. Now, it will be seen that if the work is given a small, steady advance in relation to the table, the errors, instead of lying in planes through the axis, will lie in spirals around the wheel, and that when put to work they will be obliterated and leave a true wheel.

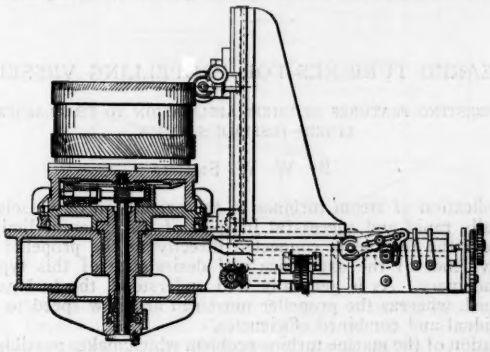


FIG. 6.—SECONDARY TABLE MOUNTED ON ORIGINAL TABLE OF GEAR CUTTING MACHINE AND TRAIN OF GEARING TO GIVE 5 PER CENT. "CREEP."

"Fig. 6 is an illustration of the adaptation of this new principle of cutting to an existing gear hobbing machine. A secondary table is mounted on the original table of the machine and given a creep in advance of 5 per cent. in relation to it by means of the train of gearing shown, the main worm driving the lower table being driven at 5 per cent. less speed, so as to secure the same rotational speed as before the creep was introduced.

"While the most important effect of this arrangement is that the errors in the teeth will lie in very oblique spirals around the wheel, resulting in great uniformity in the gearing, at the same time it has also an important effect in reducing the errors themselves."

This article has been written for the purpose of bringing to the notice of ship owners, shipbuilders and engineers the large amount of marine mechanical gearing which is under construction in Great Britain at this time, the engines of which will drive vessels across the North Atlantic and all over the world by means of steam turbines and mechanical gearing.

ADVANTAGES OF GEARED TURBINE DRIVE.

The following advantages have been clearly demonstrated for this new method of ship propulsion when compared with reciprocating-engine machinery:

1. Economy in fuel consumption, varying from 10 to 25 per cent., dependent on the type of vessel under consideration.
2. Saving in the machinery weights varying from 10 to 20 per cent.
3. Saving in engine-room space for large ocean-going vessels.
4. Less liability for broken line shafting, due to the even turning moment of turbine machinery.
5. In a single-screw vessel, with the ahead turbines of the reaction type arranged in series, either turbine can be used independently of the other, so that this lessens very greatly any chances of a complete breakdown of the main propelling machinery.
6. Splendid economy of steam consumption is obtained in the reaction type of turbine with moderate boiler pressures, varying from 150 to 175 pounds working pressures, with its consequent advantages of a lighter and safer machinery installation.

Finally, there does not appear to be any limit to the horsepower that can be transmitted through gearing suitably designed for any proposed work.—"International Marine Engineering."

GEARED TURBINES FOR PROPELLING VESSELS.

SOME INTERESTING FEATURES OF THEIR APPLICATION TO THE LARGEST EXPRESS LINER—POSSIBLE SAVINGS.

By W. W. Smith.

The application of steam turbines to the propulsion of vessels has been exceptionally rapid and successful in spite of the inherent limitations of speed where the turbine is connected directly to the propeller. This is striking evidence of the excellence and desirability of this type of propelling machinery. As is generally well understood, the turbine demands a high speed, whereas the propeller must run at a low speed to attain the best individual and combined efficiencies.

The solution of the marine turbine problem which makes possible all of the natural advantages of the turbine which result from a high rotative speed

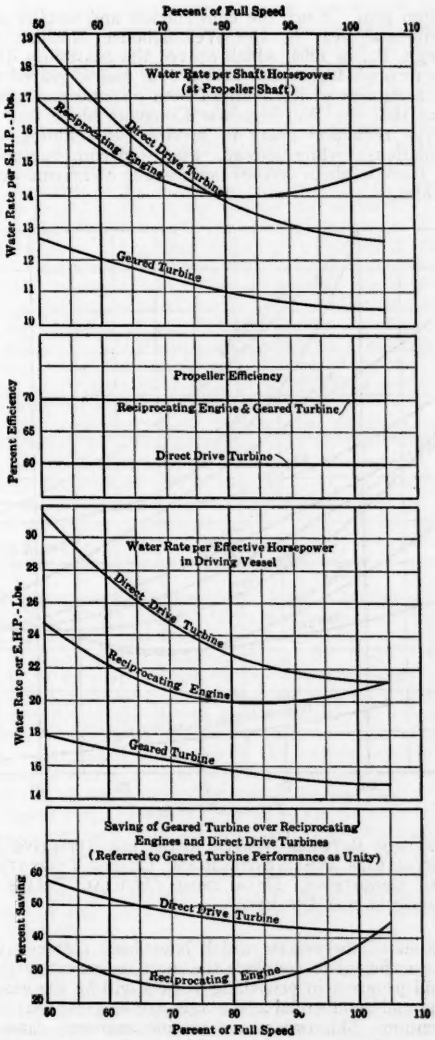

Percent of Full Speed
50 60 70 80 90 100 110
Water Rate per Shaft Horsepower (at Propeller Shaft)
Water Rate per S.H.P.-Lbs.
Reciprocating Engine
Direct Drive Turbine
Geared Turbine
Propeller Efficiency
Percent Efficiency
Reciprocating Engine & Geared Turbine
Direct Drive Turbine
Water Rate per Effective Horsepower in Driving Vessel
Water Rate per S.H.P.-Lbs.
Direct Drive Turbine
Reciprocating Engine
Geared Turbine
Saving of Geared Turbine over Reciprocating Engines and Direct Drive Turbines (Referred to Geared Turbine Performance as Unity)
Percent Saving
Direct Drive Turbine
Reciprocating Engine
Percent of Full Speed

FIG. 4.—COMPARISON BETWEEN THE PERFORMANCES OF RECIPROCATING ENGINES, DIRECT-DRIVE AND GEARED TURBINES FOR A BATTLESHIP OF 21 KNOTS AND 28,000 SHAFT HORSEPOWER, BASED ON TRIAL DATA OF RECENT BATTLESHIPS. (STEAM PRESSURE, 250 POUNDS; VACUUM, 28½ INCHES.)

is the reduction gear. Since the construction and test of a 6,000 horsepower experimental gear by the Westinghouse Machine Company, of East Pittsburgh, Pa, in 1909, which proved the possibility of transmitting large powers through high-speed helical spur gears, geared turbines have been used in a number of installations both on land and sea. It is interesting to note that the Westinghouse Company alone has 95,000 horsepower of large reduction gears in service and building for land and marine installations; while abroad, where marine engineering is less conservative, there is about 500,000 horsepower of marine geared turbines built and building.

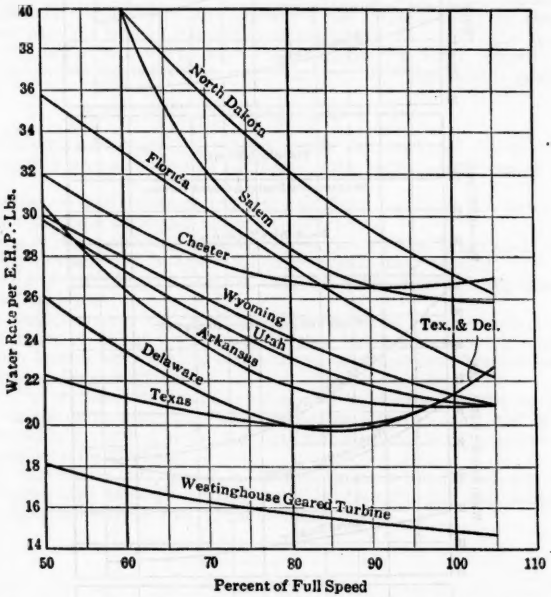


FIG. 5.—COMPARISON BETWEEN WATER RATES PER EFFECTIVE HORSEPOWER OF U. S. BATTLESHIPS AND WESTINGHOUSE GEARED TURBINES OPERATING UNDER SAME CONDITIONS. DATA FROM OFFICIAL TRIALS (TURBINES ONLY; AUXILIARIES NOT INCLUDED).

An examination of the results which have been obtained with geared turbines will be sufficient to convince the most conservative that the next step in the rapid progress in propelling vessels will be the geared turbine. The engineering and commercial advantages are so great that they demand the closest attention. Shipowners and marine engineers cannot afford to ignore such great advantages, which, within a short time, may spell success or ruin in the keen competition of the future.

In the Westinghouse turbine the steam is expanded to a considerable volume in nozzles, and the energy due to this expansion is absorbed in an impulse wheel having two rows of moving blades. When superheated steam of high pressure is used it is confined in the nozzles, where it is

expanded and very much reduced in pressure and temperature, so that the casing of the turbine is never exposed to the high pressures and temperatures which cause distortion, resulting frequently in blade troubles. As a considerable portion of the total energy in the steam is given up in the impulse wheel, there is considerable reduction in the length of the rotor, giving a short, stiff rotor, which effectually prevents vibration.

An important advantage of the compact and substantial construction of geared turbines is that they can with perfect safety be started cold and brought up to the full speed at once. In naval vessels particularly this is a matter which is often of the highest importance. With turbines directly connected to the propeller shafts, the lengths and diameters of the rotors and casings are such that, in order to prevent distortion from unequal heating and expansion, it has been found necessary in practice to bring all of the turbine machinery to the normal working temperature as nearly as possible before it may safely be set in motion. In large vessels this warming process requires several hours. The smaller dimensions resulting from the higher speed of geared turbines give a sturdier construction in which the tendency to distortion is reduced to a negligible minimum. In case of emergency, the steam, even though it carries with it considerable water of condensation, may be admitted to cold turbines, and the full speed attained in about a minute.

By locating the condenser under the turbine, which is made possible by the use of geared turbines, an exceedingly compact unit is obtained. As the steam passes directly into the condenser, the exhaust pipe and the consequent drop in pressure are eliminated. As the turbine drains by gravity, water cannot accumulate, and hence this cause of stripping the blading and of corrosion is eliminated.

LOSS OF POWER IN REDUCTION GEARS.

The highly economic performance of geared turbines is only made possible by the exceedingly small loss in transmission through the reduction gear. It has been found from tests that the loss is between one and one and one-half per cent. This means that the loss in each reduction gear proposed for a vessel similar to the *Vaterland* would be about 200 horsepower, or less than 1,000 horsepower for all four gears.

As the superiority of the helical reduction gear to other methods of speed reduction lies principally in its greatly superior efficiency, it will be of interest to compare the losses in the various systems. From the best information available, it is believed that the losses in the electric and hydraulic systems of speed reduction cannot be less than 8 per cent. and 10 per cent. respectively. Hence the loss of power with electric drive would be 5,600 horsepower, and with the hydraulic 7,200 horsepower, as compared with 800 for the helical gear. The saving of five or six thousand horsepower is of importance, not only because it represents considerable reduction in the cost of operation, but also, as should be clear from the above, because of the reduction in boiler capacity, auxiliaries, etc., in consequence thereof.

The mechanical operation of the gear is not a matter of speculation. The ability of the reduction gear to transmit large powers safely and efficiently has been conclusively demonstrated on land and sea by over 70 gears built by the Westinghouse Company. These gears have proved entirely reliable under varied and severe operating conditions. Most of them are used for large direct-current generators and operate under considerably more severe conditions than those on board ship. In many cases the units have been kept in practically continuous service for months, and subjected to frequent short circuits which instantly increase the load to several times the normal full load, thereby imposing shocks and strains on the gear much more severe than ever experienced in marine

service. They have operated successfully under the existing service conditions, which in many cases were unfavorable, and where they have received but little attention. It has been found that there is no vibration and that the operation of the gears is very quiet, the noise being negligible.

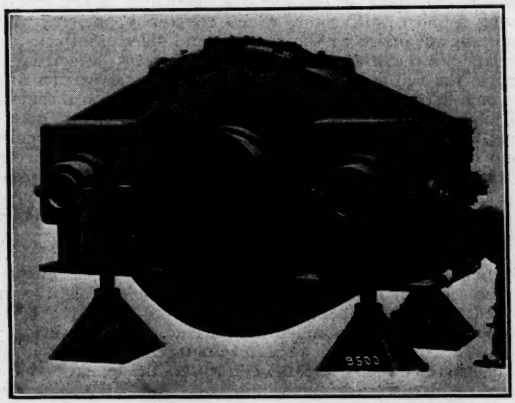


FIG. 6.—REDUCTION GEAR FOR U. S. S. "MELVILLE" ERECTED IN BUILDERS' SHOP. REVOLUTIONS PER MINUTE, 1,400 TO 110; SHAFT HORSEPOWER, 4,000; DIAMETER OF GEAR, 95 INCHES; DIAMETER OF PINIONS, 7½ INCHES; WEIGHT, 64,000 POUNDS.

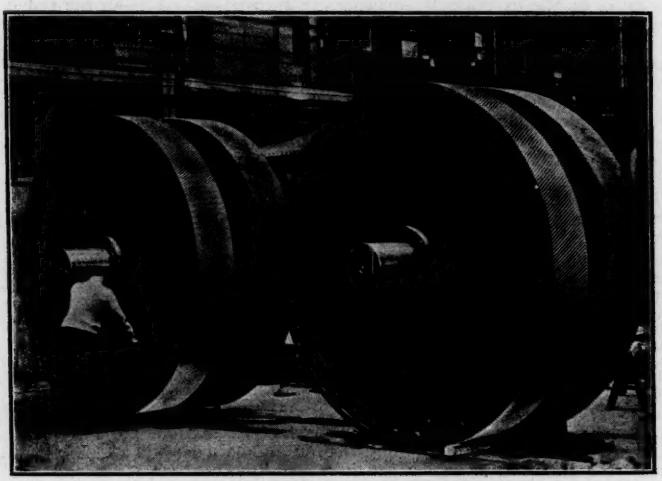


FIG. 7.—GEAR WHEELS FOR 35,000 HORSEPOWER REDUCTION GEARS. DIAMETER OF GEARS, 120 INCHES; DIAMETER OF PINIONS, 7 INCHES; REVOLUTIONS PER MINUTE, 1,900 TO 110.

In every case the teeth have taken a brilliant mirror-like polish, which forms a dense, hard skin of exceeding durability on the working surfaces. The wear on the teeth is exceedingly small, and in many cases it has been impossible to detect by accurate measurement of the teeth any wear whatever in gears which have been in service for over two years. It has been demonstrated beyond question that the life of the gear is very long, and that it will exceed the life of the ship.

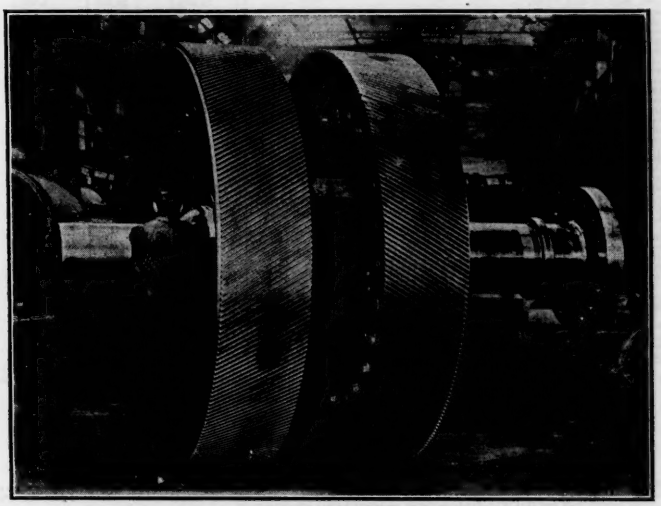


FIG. 8.—GEAR WHEELS FOR 6,000 HORSEPOWER REDUCTION GEAR. REVOLUTIONS PER MINUTE, 1,800 TO 180; DIAMETER, 100 INCHES. THIS GEAR HAS BEEN IN SUCCESSFUL OPERATION FOR OVER A YEAR AND A HALF.

TRANSMISSION OF LARGE POWERS.

The ability to transmit large powers has been conclusively demonstrated by the fact that the Westinghouse Company have built and operated with entire success the following large gears: Three of 6,000 horsepower, one of 4,000 horsepower, five of 3,500 horsepower, and seven of 2,000 horsepower. Four of the 2,000 horsepower gears have been in service for over three years driving direct-current generators. Two of the 6,000 horsepower gears, which also drive direct-current generators, have been in service for more than a year and a half and have proved most satisfactory in every way. The gears installed on the U. S. S. *Neptune* were tested under all of the various service conditions, and were found entirely satisfactory by the Navy Department. The fact that all of these large gears without exception have operated with entire satisfaction, and that there have been no failures whatever in large gears, should be ample assurance that they are, beyond question, absolutely reliable. They are completely removed from the experimental stage, and, as experience has proved conclusively, they are entirely suited for marine service.

COMPARISON BETWEEN GEARED AND DIRECT-DRIVE TURBINES FOR EXPRESS STEAMER VATERLAND

	Direct-Drive Turbines	Geared Turbines	Actual Saving	Percent Saved
1. R.P.M. of propellers for 23½ knots	170	130	.....	....
2. R.P.M. of turbines—H. P.	170	1,800	.....	....
3. R.P.M. of turbines—L. P.	170	1,650	.....	....
4. Number of reductions—H. P.	.....	13.8	.....	....
5. Number of reductions—L. P.	.....	12.7	.....	....
6. Propeller efficiency—percent.	60	65	.....	....
7. Horsepower, effective for 23½ knots	43,200	43,200	.....	....
8. Horsepower, shaft for 23½ knots	72,000	66,500	5,500	7½
*9. Steam consumption per S.H.P. hr. lbs.—turbines	11.8	9.0	2.8	24
10. Steam consumption per S.H.P. hr. lbs.—auxiliaries	1.8	1.5	.....	....
11. Steam consumption per S.H.P. hr. lbs.—all purposes	13.6	10.5	.....	●
*12. Steam consumption per I.H.P. hr. lbs.—all purposes	12.5	9.65	.....	....
13. Steam consumption per E.H.P. hr. lbs.—turbines	19.7	13.8	5.9	30
14. Steam consumption per E.H.P. hr. lbs.—all purposes	22.7	16.2	6.5	28
*15. Coal consumption per S.H.P. hr. lbs.	1.51	1.17	.....	....
16. Coal consumption per I.H.P. hr. lbs.	1.39	1.08	.....	....
17. Coal consumption per day—tons	1,165	835	330	28
18. Coal consumption per voyage of 3,520 miles—tons	7,270	5,210	2,060	28
19. Coal consumption per year (24 voyages)—tons	174,600	125,000	49,600	28
20. Weight of main turbines (and gears)—tons	2,600	500	2,100	81
21. Weight of all other machinery—tons	4,500	3,600	900	20
22. Weight of all machinery—tons	7,100	4,100	3,000	42
23. Weight of coal required (bunker capacity)—tons	8,200	5,900	2,300	28
24. Weight of machinery and coal—tons	15,300	10,000	5,300	34½
25. Space, floor, occupied by turbines and gears—square feet	3,574	1,760	1,814	51
26. Space, floor, length for all machinery—feet	534	394	140	26
*27. Space, volume for all machinery—cubic feet	1,516,000	1,121,000	395,000	26
28. Turbines, weight of largest—tons	330	33.5	316	90
29. Turbines, weight of largest rotor—tons	135	11	124	92
30. Turbines, number of blades	750,000	160,000	590,000	79
31. Turbines, number of miles of blading	122	11.3	111	91
32. Boilers, number	46	33	13	28
33. Boilers, heating surface—square feet	203,000	146,000	57,000	28
34. Condensers, cooling surface—square feet	65,000	46,800	18,200	28
35. Fire room force, number of men	390	296	94	26
36. Cost of coal per day (at $3.25 per ton)—dollars	3,780	2,710	1,070	28
37. Cost of coal per voyage—dollars	23,600	16,900	6,700	28
38. Cost of coal per year—dollars	568,000	406,000	162,000	28
39. Cost of fire room force per day—dollars	331	245	86	26
40. Cost per fire room force per voyage—dollars	2,070	1,530	540	26
41. Cost of fire room force per year—dollars	119,000	87,700	31,300	26
42. Cost of machinery—dollars	1,900,000	1,200,000	700,000	37
43. Cost of interest, insurance, amortization, repairs and supplies—dollars	283,000	180,000	105,000	37
44. Earning due to 5,300 tons additional cargo capacity—dollars	.....	.....	600,000	....

*9. Steam pressure 235 pounds gage; vacuum, 28½ inches. *15. Evaporation, 9.0 pounds. *12. S.H.P.=I.H.P. × .92. *27 Below deck, 4.

SUMMARY OF SAVING (PER YEAR) DUE TO USE OF GEARED TURBINES.

Coal	$162,000.00	(£33,200)
Fire room force	31,300.00	(6,420)
Fixed charges, repairs and supplies	105,000.00	(21,500)
Additional earning due to enlarged cargo space	600,000.00	(123,000)
Total saving and increase in revenue	$898,300.00	(£184,000)
Total saving and increase in revenue, per S.H.P.	$12.50	(£2.6)
Capitalized value of total saving at 6 percent—$15,000,000 (£3,080,000).		

NOTE.—The information for the above table was obtained from various sources and is the most reliable obtainable. While some of the values were assumed, it is believed that they agree very closely with the actual. However, it should be understood that the table is based on assumptions and that it is only intended to represent a close approximation.

While 67,000 horsepower, such as would be needed for the *Vaterland*, is tremendous, the gears required would be but very little larger than the ones already built, and would be well within the possibilities demonstrated. The power transmitted by each of the eight pinions would be only 8,300, or but 2,300 horsepower more than the 6,000 horsepower experimental gear. If it were desirable, 50,000 horsepower could without difficulty be

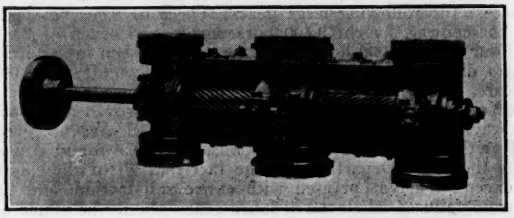


FIG. 9.—HYDRAULIC FLOATING FRAME WITH PINION IN PLACE, SHOWING FLEXIBLE DRIVING SHAFT AND COUPLING, AND THE CYLINDERS WHICH SUPPORT THE FLOATING FRAME AND FORM THE DYNAMOMETER FOR MEASURING THE POWER TRANSMITTED.

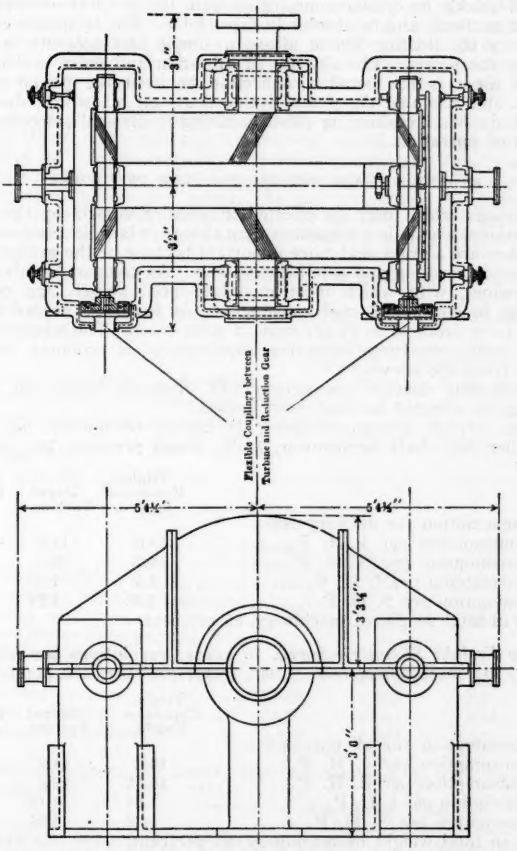


FIG. 10.—REDUCTION GEAR FOR U. S. S. "PENNSYLVANIA." REVOLUTIONS PER MINUTE, 1,800 TO 120; SHAFT HORSEPOWER, 1,600; DIAMETER OF GEAR, 70 INCHES; WEIGHT, 30,000 POUNDS.

transmitted to each shaft, as compared with the 16,600 per shaft in this case. It is plain, therefore, that even the greatest powers which are contemplated for driving vessels can be transmitted through gears without difficulty.

The success of the large gears built by the Westinghouse Company, and their ability to transmit large powers, are due to the hydraulic floating frame, which automatically align the pinion and the gear under all conditions of load, so as to distribute the load uniformly over the entire length of the broad gear faces, thus avoiding intense local pressure which would otherwise occur. The floating-frame gear can be overhauled and

assembled quickly by ordinary mechanics with the absolute assurance that it will run perfectly and be absolutely dependable. The hydraulic cylinders which carry the floating frame afford a simple and accurate means of measuring the power. The absence of vibration and noise is due to the fact that there is no metallic connection between the pinion and the gear box, and also that the pinion frame floats on oil, which, due to the entrained air, has a cushioning effect resulting in unusual smoothness and quietness of operation.

REDUCTION GEARS SUITABLE FOR SLOW FREIGHTERS.

The savings which may be effected in smaller vessels by the use of geared turbines are no less important than those for large express steamers. In fact, they are a great deal more important because of the greater aggregate power in medium and small-size vessels. As compared with reciprocating engines, with which most moderate-speed vessels are equipped, the saving in steam and coal consumption in favor of geared turbines is found to be from 15 to 25 per cent. in most cases. The advantages and financial saving resulting from this improvement in economy should be apparent from the above.

The following specific comparison will illustrate briefly the savings which may be effected in slow-speed vessels:

1. *Large Freight Steamer.*—Speed, 14 knots; revolutions per minute of propeller, 90; shaft horsepower, 5,500; steam pressure, 200 pounds.

	Triple-Expansion Engine.	Geared Turbine.	Per Cent. Saved.
Steam consumption for all purposes—			
Steam consumption per I. H. P.....	15.0	11.1	25.7
Steam consumption per S. H. P.....	16.3	12.1	25.7
*Coal consumption per I. H. P.....	1.5	1.1	25.7
Coal consumption per S. H. P.....	1.63	1.21	25.7

Saving in total weight of machinery, 29 per cent.

2. *Slow Freight Steamer.*—Speed, 10 knots; revolutions per minute of propeller, 70; shaft horsepower, 2,500; steam pressure, 180 pounds.

	Triple-Expansion Engine.	Geared Turbine.	Per Cent. Saved.
Steam consumption for all purposes—			
Steam consumption per I. H. P.....	15.5	11.8	23.5
Steam consumption per S. H. P.....	16.75	12.8	23.5
Coal consumption per I. H. P.....	1.55	1.18	23.5
Coal consumption per S. H. P.....	1.68	1.28	23.5

Saving in total weight of machinery, 27 per cent.

From a commercial viewpoint the large savings which may be obtained by using geared turbines are most attractive. No doubt they will be compelling within a short time. In some cases the first cost of geared turbines may be slightly higher than reciprocating engines, but when the savings are capitalized it is found that engines are the most expensive at almost any price. In some cases it is found that it would not pay to put in an engine, even if it were obtained absolutely free.

ADVANTAGES OF REDUCTION GEARS IN NAVAL VESSELS.

In naval vessels the military advantages of geared turbines are quite as great and important as are the commercial advantages in merchant vessels. The saving in weight and space required for the machinery makes

*Actual evaporation, 10.0 pounds.

it possible to considerably increase the gun power or armor protection. In the case of the *Nevada,* for example, the saving in the weight of machinery and coal would make it possible to add another turret, with the necessary ammunition, etc., thus increasing the battery from ten to twelve 14-inch guns, or, in other words, increasing her defensive power by 20 per cent.

One of the most important advantages of geared turbines for naval vessels is their high efficiency at cruising speed, in which respect the direct-drive turbine has been found lamentably lacking. This is well illustrated in Fig. 5. These curves would also apply to merchant vessels of about the same power and speed. As the curves for the reciprocating engine are based on the *Delaware* and *Texas,* which have exceptionally efficient engines, they are somewhat better than the average results obtained with this type.

The following comparisons will illustrate the advantages of geared turbines for naval vessels:

1. *Battleship.*—Speed, 21 knots; shaft horsepower, 28,000; steam pressure, 250 pounds.

	Direct-Drive Turbine.	Geared Turbine.	Per Cent. Saved.
Revolutions per minute of propellers.....	320	125	
Steam consumption in pounds per effective horsepower per hour in driving vessel at full speed ..... (Turbines only.)	21.2	15.0	29
Same at cruising speed.....	27.8	17.0	38

Saving In Weight (Tons).

	Direct Drive.	Geared Turbines.	Actual Saving.	Per Cent. Saved.
Main turbines only	650	300	350	54
Other propelling machinery, boilers, auxiliaries, etc.....	910	673	237	26
Ship's auxiliaries (not part of propelling machinery)	500	500	0	0
Propelling machinery only.....	1,560	973	587	37½
All machinery	2,060	1,473	587	28½
Fuel (full capacity).....	2,500	1,730	770	31
All machinery and fuel.....	4,560	3,203	1,357	30

2. *Destroyer.*—Speed, 30 knots; shaft horsepower, 18,000; steam pressure, 250 pounds.

	Direct-Drive Turbine.	Geared Turbine.	Per Cent. Saved.
Revolutions per minute of propellers....	600	450	
Steam consumption in pounds per effective horsepower at full speed..... (Turbines only.)	19.5	15.5	20
Same at cruising speed.....	28.5	18.0	37
Saving in total weight of machinery, per cent.....			22
Saving in total weight of fuel, per cent.....			31
Saving in total weight of machinery and fuel, per cent.....			28

With geared turbines the additional complication and weight of cruising turbines are not required. With respect to backing power and quick maneuvering, which are very important in naval vessels, the direct-drive turbine has not been entirely satisfactory because of the small propellers and restricted astern power. Because of the large propellers, which "take hold of the water," and the ample backing power which can be

obtained in high-speed turbines, the backing and maneuvering qualities of geared turbines are quite satisfactory and practically as good as obtained with reciprocating engines. This is also an important consideration in merchant vessels, especially those which have to be handled around docks.

The advantages of geared turbines for propelling vessels, both naval and merchant, are of the greatest importance. Now that the reduction gear has made it possible to realize the full advantages of the turbines, its rapid adoption seems certain. A few years ago the turbine wiped out the reciprocating engine on land. It now appears that this same stage has been reached at sea, and that here also the turbine will wipe out the reciprocating engine.

FOETTINGER TRANSFORMER. Recent development of the Hydraulic Transformer, by Dr. H. FOETTINGER. Read before the Institution of Naval Architects, July 7, 1914. Article largely reproduced in "The Steamship," Sept., 1914; "Cassiers Engineering Monthly," Sept., 1914; "The Engineer," Sept. 11, 1914. The article in "The Engineer" also contains comment upon the paper, and comparisons with other recent vessels. The apparatus is fully illustrated in "Cassiers Engineering Monthly."

THE EFFICIENT MAINTENANCE OF TURBINE MACHINERY.

BY LIEUTENANT REVORD.

NOTE.—This article is reproduced from the "Shipbuilder," September, 1913; it gives what may be considered practical notes on British practice. While the installations built in the U. S. differ somewhat from those referred to in this paper the principles involved are much the same. The method of warming up herein described is not usually followed in the U. S., where the so called quick method (see page 1272 this number) is used.—H. C. D.

The question of marine steam turbine efficiency is still engaging the close attention of our leading shipbuilders and engineers, and it is proposed in this article to deal with the methods adopted to ensure economical working, to maintain efficiency, and to reduce the chances of breakdown with this type of engine. As is well known, for high-speed liners and warships, the turbine has proved its many advantages; but where economy is the order of the day and great speed is not essential, the reciprocating engine more than holds its own. Again, in a marine turbine, should a rotor or casing strip, the whole of the plant is put out of action, and the re-blading of either motor or casing is a long and expensive job.

Lubrication.—The question of efficient lubrication plays a most important part in the case of turbines, as it is essential that the lubricating oil is supplied in a regular and steady manner. The failure of the lubricating system would undoubtedly result in the rapid heating of the various bearings, thus causing the white metal in the bearings to melt and the rotors to drop, with grave danger of stripping of both rotor and casing blades.

Before mentioning the precautions to be observed, it would be as well to explain briefly the system of forced lubrication now fitted to all modern turbine installations. The oil is drawn from a drain or supply tank, through a filter, by means of small Weir's pumps. These pumps discharge through a cooler into the various bearings, and thence back into the same tank. The tank, in the first place, receives its supply from a "settling" tank, this tank being fed from the reserve-oil tank. Collars are turned on the rotor shafts at each end of each bearing, in order to prevent the oil working along the shaft and so running to waste. In addition to these collars, thin metal plates are arranged outside the bearings themselves, and these further act as

waste preventers. The various bearings receive the oil through channels cast in the framing, and wells are provided to receive the oil after use. These wells are placed in connection with the supply tank, to which the oil flows after doing its work in the bearings. Discharge pipes lead the oil from the cooler to the various bearings, one set feeding the main bearings and thrusts, and the other the plummer blocks. The cooler consists of a number of tubes somewhat similar to a condenser, through which sea water is circulated, and test cocks and hand doors are provided for inspection purposes.

For efficient lubrication, the following precautions must at all times be observed. Oil pumps must be started and the flow of oil observed through all bearings before the steam is admitted to the turbines. Cooler and circulating water for same must be efficient, the absence of water from the oil drain and settling tank ensured by frequent opening of the drain cock, and the efficient flow of the oil ascertained by close attention to pressure gages and oil cocks. Should the oil thicken while steaming, it should be renewed as necessary from the settling tank. After the turbines are finished with, the contents of the drain tanks must be pumped into the settling tank and allowed to settle, the thick oil being then drawn off. All oil strainers and wells fitted under the bearings should be frequently examined and, if necessary, cleaned out. Should the lubrication from any cause become stopped, the various gages fitted to the pumps, coolers, and bearings will indicate the fact at once, and too much care cannot be take in the careful observation of the gages. Should traces of oil be found on the internal surfaces of the boilers, it usually points to the fact that excessive oil has been used when swabbing the rods of the auxiliary engines. Especially is this noticed when excessive oil has been used on the plunger rods of the feed pumps, in which case, of course, the oil passes directly to the interior of the boilers in use.

Vacuum.—The maintenance of a good vacuum is more essential in a turbine than in a reciprocating engine, on account of the greater range of expansion. To obtain this increased vacuum various methods have been adopted, and the condensing plant especially requires careful consideration. Various condensers have been evolved to this end, a noted and successful example being the "Contraflo." In some cases a vacuum augmenter is fitted. This apparatus consists of a small steam jet, placed in a contracted portion of a pipe which is led from the bottom of the condenser. The jet draws air from the condenser and delivers it to the air pump through a small cooler, the air being thus reduced to a negligible quantity.

The various causes of low vacuum and the steps taken to remedy this defect will now be considered.

1. Leakage of air pumps drains to bilge.—This may be detected by means of a flame, or feeling, and can be easily rectified.

2. Cooler working inefficiently.—This is probably due to the salt water connection being choked, or only partially open.

3. Air pump valves or plungers inefficient owing to various causes.—In this case the valves and plungers must be examined at the first available opportunity and refitted as necessary.

4. Exhaust steam being improperly condensed.—This is usually caused by the speed of the circulating pumps being too slow, and is of course rectified by increasing the pump speed, first ascertaining that the weed traps and inlets are all clear.

5. Auxiliary exhaust system drains being left open.—This can be seen by screwing up the loaded valves on the auxiliary exhaust system and so putting pressure in the auxiliary exhaust.

6. Glands of condenser fittings leaking, or condenser escape valve defective.—This is ascertained by means of a candle flame.

7. Drain valves to bilge in drain pipe from turbines open, or leakage in run of drain pipes from suction of wet-air pump.—This is detected by means of a candle flame. It is sometimes found that the eduction pipe between the L.P. turbine and condenser is so badly designed that the steam is un-

equally distributed over the cooling surface of the condenser. This defect is shown by variation in temperature along the body of the condenser, the vapor probably passing into the air-pump suction pipe. The only remedy for this is the addition of baffles, or the alteration of the baffles already fitted.

The Utilizing of Exhaust Steam in Turbines.—The use of exhaust steam is an important factor in turbine-engine economy. The usual method adopted is to create a pressure in the auxiliary exhaust service and utilize this pressure in doing useful work in a certain turbine or turbines, depending of course on the pressures in the system or turbine. Usually this exhaust can be maintained at a pressure of from 25 to 30 pounds per square inch, and this admitted to the turbines, especially at low powers, gives a material gain in efficiency and economy.

The general arrangement is as follows: The auxiliary exhaust is led into each condenser through a spring-loaded valve on the latter, these valves being regulated to give such back pressure in the exhaust as necessary to cause the exhaust steam to flow into the turbines through non-return valves, thus preventing any flow back with the exhaust. It is usual to provide for this exhaust steam to flow into either (*a*) the H.P. turbine, third expansion, (*b*) the L.P. receivers, or (*c*) the L.P. turbine, depending on the pressure in use.

In connection with the auxiliary exhaust system, care must be taken to draw off any water in the pipe leading to the particular valve to be used, before opening the valve. The exhaust steam must be shut off from the turbines the moment orders are received for maneuvering, and the exhaust thus allowed free passage to the condensers.

Loss by Skin Friction.—This loss is due to the skin friction of the steam, flowing at such high velocity through the comparatively small spaces between the blades. The loss may be reduced by superheating, and thus partially removing the fluid frictional loss, caused by the particles of condensed water mixing with the steam.

Eddy Current Lines, Due to Errors in Workmanship, or to Insufficient Blade Velocity.—This loss does not occur to any appreciable extent with large compound or sinuous-course turbines, but in the single-wheel type it is present to a considerable extent.

Unavoidable Leakages.—These losses decrease as the size of the turbine increases, chiefly consequent on the coefficient of expansion of metals. Could a metal be obtained with a smaller coefficient of expansion than iron, and at a fair price, a large increase in economy would result, as it would allow of much smaller clearances, and consequently less leakage.

Cavitation.—In turbine propellers the blades are much broader in proportion to their length than is the case with the ordinary reciprocating-engine propeller, due to the diameter of the propeller being of necessity much less; and in order to obtain the requiste blade area, a much larger ratio of blade surface to disc surface is necessary. Cavitation usually occurs when the propellers are revolving at high speeds, causing reduced propeller efficiency as the slip is increased. With the earlier turbine propellers, cavitation was a great source of inefficiency, and even now, in many cases, the same trouble occurs. Propellers of varying design are therefore experimented with in order to ascertain the type of blade which will give the greatest efficiency. In several cases of fast torpedoboat destroyers the different results obtained with the various types of blades were most marked, and, although the present turbine propeller blades yield good results, much experimental work still remains to be done in this direction before the perfect turbine propeller blade is evolved.

The Procedure Adopted when Raising Steam in Marine Turbines.—Raising steam with turbines is a much more complicated matter than in the case of the reciprocating engine, and if the turbines are to be maintained in an efficient condition too much care cannot be expended when raising steam. The following method of procedure should be adopted in order to give the best results:

Six hours are usually allowed for warming through, but in many cases this time is greatly exceeded. In some of the big warships as much as twenty hours are allowed. The requiste number of boilers should be lighted, one furnace in each, and the drains on the run of piping opened. The engine-room bulkhead valves are opened and any drain valves attached, first seeing *all* turbine drains opened to the bilge. Ease off the master steam valves to the glands and also the steam valves on the glands themselves. The leak-off valves in connection with the same should now be opened. Carefully see that the turning gear is pinned out of gear. The self-closing valves between the turbines must now be examined so as to ascertain if they are free to open, and the regulating and self-closing valves as fitted should be eased off. This is necessary to allow the steam to flow through the series of ahead and astern turbines, so that the steam is free to enter at the highest pressure turbine and flow through the other turbines to the condenser. In the cases where maneuvering valves are fitted to supply steam to the L.P. and astern turbines, the direction of flow must be frequently reversed. When warming up, the flow of steam should never be sufficient to revolve the rotor. The other boiler furnaces are lighted as required, so as to gradually warm up the whole system. When steam allows, the main circulating, feed and air pumps must be started, and also the oil-lubricating pumps, making certain that these latter are working satisfactorily. It must also be ascertained that the circulating water to the oil cooler is flowing properly. In the cases where the pumps mentioned have auxiliary connections, these connections must be tried at the earliest opportunity. When the turbines are all thoroughly warmed up, and the cylinders have expanded in the fore-and-aft direction to agree with original clearances and amounts as shown by the various gages, the rotors should be given a few turns ahead and astern. The oil discharge should not fall below 8 pounds per square inch, and the temperature of the oil in the bearing wells should be tested at intervals. The steam pressure at the glands is kept as low as possible, consistent with the prevention of air leaking to the glands (which would, of course, reduce the vacuum) and with the pressure in the particular turbine.

The above seemingly elaborate precautions can be well understood when the very fine clearances between the blades and casings of the rotors in the first place, and between the dummy rings and dummy grooves in the second place, are considered. Should all precautions not be observed, contact might ensue between the latter, and probably the former, owing to warping, and this might easily result in the stripping of the blades. Too much care cannot be taken in using the steam connections to the glands, in order to ensure expansion of the rotor spindles, and thus keeping the clearances correct. It must be noted here that the turbines should never be moved until the feet have moved to within their recorded limits.

Working Adjustment of Marine Turbines; the Dummy Clearance.—This clearance is the longitudinal adjustment of the turbine, and the operation must be carried out when the turbine is thoroughly hot. This clearance is a most important detail in the efficiency and economy of the turbine, and the utmost care must be taken in its careful observation. The method of procedure is as follows:

By means of the gear provided, bring up the rotor until the dummy rings and grooves are in actual contact. Note the clearance at the finger plate, and screw back the rotor until the clearance is increased by perhaps $\frac{25}{1000}$ths of an inch. Liners of the necessary thickness to bring the lower half thrust rings up against the forward faces of the shaft collars can be fitted in place, and the lower half will then be locked in position. The astern or upper portion of the thrust is now dealt with as follows: Ease the nuts of the cover studs, and work the adjusting screw until the rings and collars are in actual contact. Tighten the cover-stud nuts, and screw back the adjusting stud till the micrometer feelers between it and the turbine casing show the necessary oil clearance, say about $\frac{5}{1000}$ths of an inch. Ease back the cover

nuts, and tap up the top half till the clearance becomes nil. Screw the cover bolts down hard. We then get $\frac{5}{1000}$ths oil clearance and a dummy clearance of $\frac{35}{1000}$ths of an inch. With turbines it must be noted that excessive clearance is a big factor in the uneconomical working of the plant, as, should too much steam be allowed to pass by the blades, a large increase in fuel consumption will result. With a fairly large plant, the following clearances should prove suitable: H.P., 19; M.P., 19; L.P., 24; cruising, 14; all in thousandths of an inch.

Gaging the Wear Down of Bearings.—To detect the wear down of the rotor shafts, an appliance called a bridge gage is employed. The gage consists of a piece of square steel, bent as shown in Fig. 2, and provided with a central boss. Through this boss a hardened steel pin, with a flat point, is screwed. The bridge piece is fastened to the lower half casing, just outside the gland. The pin is adjusted to a known clearance from the top of the shaft, so that by applying the instrument any drop of the shaft is at once detected by means of feelers between the top of the shaft and the flat point of the pin. The importance of frequent examination of the wear down is apparent. The surface of the bed to which the gage is attached should be protected by means of small plates, to prevent interference with its true surface when the gage is not in use.

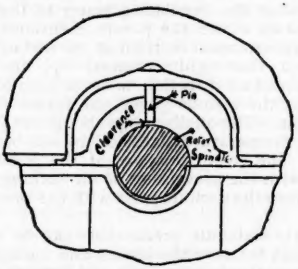


Fig. 2.—Bridge Gauge.

Repairs.—Apart from reblading, the ordinary repairs to bearings, pumps, valves, etc., of turbine machinery approximate closely to the repairs carried out in ordinary marine practice, and it is therefore not proposed to deal with them in the present article. It can be seen, however, that as turbine clearances are so much finer than in the case of reciprocating engines, much greater care must be taken in remetalling and machining bearings and brasses. Turbine-casing covers should not be lifted more frequently than is absolutely necessary. Once in three or four years should be ample, as this lifting is liable to cause distortion. All necessary examinations should be made through the sight doors.

Reblading Rotor.—Although reblading is a repair which cannot be carried out by the ship's staff, as it necessitates the removal of the rotor to the machine shops, the importance of this repair is such as to warrant an explanation of the latest method employed. In reblading the rotor, the old blades are first removed from the rotor, and a wedge piece is then fixed in the groove. Against this a caulking piece is placed, then alternately a few blades and caulking pieces. Next drive up towards the stop in the convex side of the last caulking piece with the special driving tool. Continue the process, occasionally tapping the blades home by light blows on the tips, until the wedge piece is again reached. Lightly caulk the first dozen or so caulking pieces, so as to take the strain of the wedge piece. Remove the latter, and fill up the gap with blades and packing pieces. These must be

packed very lightly. Now commence caulking, and continue all round the rotor. The caulking tool must be of the exact section of the caulking piece, and rounded at the edge to prevent damage to the blades. A recess is made in the face of the tool to mark the packing pieces when caulking. As the caulking proceeds, the blades are trued up radially and axially. The same number and weight of blows must be given to all caulking pieces in the same row; usually two blows are sufficient. The weight of the hammer must be adjusted to accommodate the size of the blades and caulking pieces. The shrouding wires are next inserted in notches, the outer one being laced into the blades. The lacing wire is then soldered into the blades. The wire is fixed on with the silver solder, the composition being: Silver, 55.7 per cent.; copper, 26.3 per cent.; tin, 6.3 per cent.; and zinc, 11.7 per cent. In this operation great care is necessary, as the melting point of copper wire and blade material is very little higher than that of silver solder. For this operation, the gas jet and blow pipe are employed, the hand-brazing lamp being of little use.

Reblading Casing.—For reblading the casing, first remove the old blades, and then fit and fix in position both stops. Next proceed as for the rotor, driving up towards the male stop until the groove is lightly packed. Caulk as for the rotor, but commence at two points half way down to the crown and work in both directions. This reduces the spring of the casing, due to caulking, to a minimum. The shrouding, lacing, and soldering are as for the rotor lacing, the shrouding wires being secured to the blade stops and the latter being faced off flush with the joint. All the striking should be done on the caulking pieces, and on no account should the blades be struck. The segments are from 2 to 3 feet long, the caulking wire being caulked into the end blade of each segment. In long blades sliding bayonet joints are sometimes fitted, to avoid breaking the binding-wire support. When fitting the segments into place, they are first lightly caulked, then the binding strip and lacing wire joined up, and the caulking is completed. On the completion of the reblading of the rotors and casings, the blades are tipped in order to give the correct clearances and cleaned by the air blast. It is sometimes found that the casings distort during the process of caulking, but they usually assume their correct shape when the halves are bolted together. Some manufacturers still prefer the independent type of blading, but the segmental type is the more general. In the former case, the blades and packing pieces are rove on a root wire; the binding, wiring and lacing being as described for the segmental process. The root wires are soldered at the ends, and finally filed off flush.

Procedure Adopted in Opening Out Turbines, and Precautions Observed.—Lifting blocks are provided, rolling on overhead rails, for lifting the top halves of the turbine casings and rotors, two eye plates being fitted at each end of each top casing. As it is most important that both the top turbine casing and the rotor should be lifted at right angles to the casing joint, as otherwise they would sway and so damage the blades, graduated pillars are fitted at the casing corners to guide the covers, and standards are supplied, which bolt to the bearing frame and fit against the journals of the rotor shaft, to guide the rotors. The openings are first blanked with wooden flanges. We next remove the casing bolts; these are numbered. In the case of the L.P. turbine the bolts must be taken out in the astern casing joint. All parts must be protected from dirt and dust. The joint is started by means of the starting bolts until the cover is just off the face. The guides are next fitted in place in the corners, and these are checked when lifting to ensure the cover coming up level. Care must be taken that the top half of the gland sleeve is not allowed to fall out when lifting, and thus allow the possibility of damage to the fin blades. Once clear of the rotor, swing away and lower. Remove the bearing caps, thrust and main, and fix the rotor guide standards in position so that the dummy does not foul when lifting, care being taken that all the lifting gear is not fouling the end of the dummy ring. The rotor is now lifted, and when the shafts are clear of the

bearing remove the bottom ends of the glands where the inner ends project beyond the end of the rotor drum or dummy ring. Complete the lifting, and allow the rotor to rest in the blocks fitted between the lifting standards. Examine the gland ring and fin blades. After a thorough inspection of the blades, the bottom half of casing, etc., etc., clean all the flanges, gland cases, etc.; clear all dirt by air pressure. Clear all the drain holes in the ahead and astern casings and also in the rotor drums. Graphite paint should be applied where the gland casings touch the gland sleeves. Replace the gland rings. The interior of the rotor is now coated with blacklead and the rotor lowered into place, and it must not be omitted to replace the bottom half of the gland sleeve before dropping into the bearing. Canvas screens should be rigged over all to exclude dirt and dust. The joints, etc., on the top half casing are next cleaned and the casing carefully lowered, and when about a foot from the joint the top half of the gland sleeves are replaced. Graphite paint is placed on the joints, and note that the dummies are midway in the grooves. Lock the rotor when possible. Note that the gland sleeves are in position, and lower finally. The bolts must be in the correct stamped positions and must be hammered up gently, and they should be gone over at least twice so as to lessen any damage by straining.

Breakdown.—Two main causes of breakdown may be mentioned:

1. Drop the main bearings—caused in almost every case by the failure of the lubricating system.

2. Incorrect position of rotor longitudinally—owing to careless gaging.

In the above cases, stripping of dummy rings would result.

Stripping of blades is usually brought about by one of the following causes:

(*a*) Drop of main bearings as above.

(*b*) Insufficient clearances between rotor blades and casing when the turbine is hot.

(*c*) Introduction of large bodies of water with the steam. This causes unequal expansion inside the turbine, and with very fine clearances might cause fouling. The importance of effective drainage is thus seen.

The above causes are those chiefly responsible for breakdown, but there are several theories advanced to meet the cases where, through no apparent cause, complete stripping of a rotor and casing has occurred. In one particular case, which came under the writer's notice, the cruising turbine, with the rotor and casing, was entirely stripped through no apparent cause. The vessel at the time was steaming at 14 knots and the cruising turbine was in use. All clearances were correct to gage, and the only theory possible was that the cruising rotor shaft had whipped and the blades of the central portion had come into contact with the rotor casing. The latest practice is to give a little more blade tip clearance at the center of the rotor shaft, thus obviating the risk of contact should the rotor whip.

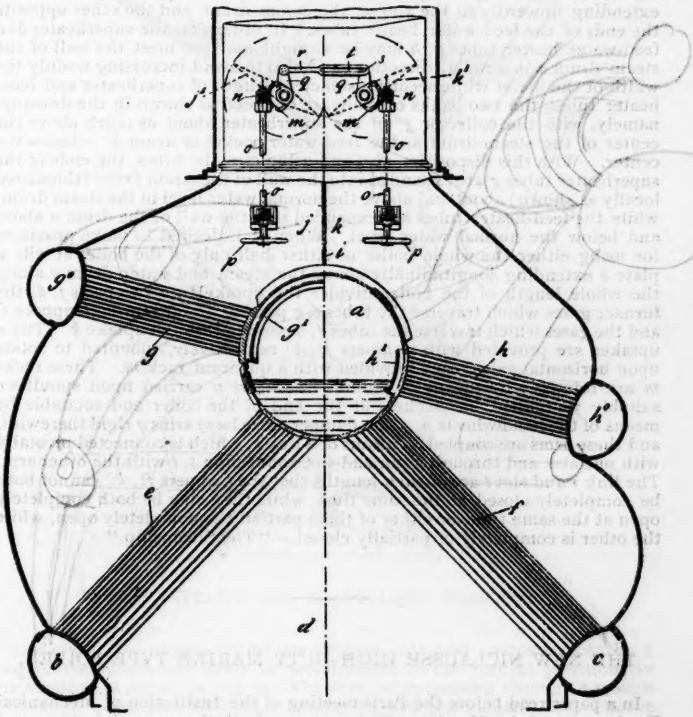
Another case occurred when running trials with a new torpedo boat. Orders were received to increase from cruising to full speed. The steam was, therefore, shut off the cruising turbine and the temperature in the casing dropped considerably. After running for a short time a humming noise was heard in the cruising casing and, on arrival in port, the cruising cover was lifted. Although no actual damage was done, the tips of the blades were brightened and had been in contact with the rotor casing. As all adjustments and clearances were correct, it was considered that, when the H.P. steam was shut off the cruising turbine, unequal expansion of the rotor and casing had occurred, thus causing the casing and blades to touch.

MARINE BOILERS.

RECENT DEVELOPMENTS ABROAD.

YARROW'S PATENT WATER-TUBE BOILER.

This illustration shows the latest improvements in Yarrow's patent water-tube boilers. This invention consists in a construction of water-tube boiler which is characterized by the combination of a steam and water drum, two water drums at a lower level, one on each side of the furnace and connected with the steam and water drum by banks of water tubes, a superheater upon one side of the boiler between the generator tubes on that side and the uptake,



and a feed-water heater similarly situated upon the other side of the boiler. The superheater tubes and feed-water heater tubes, as well as the generator tubes, are all straight, the superheater tubes entering the steam drum approximately at or above the normal water level in the steam drum. The superheating tubes and feed-heating tubes are of such lengths that they can

be drawn into the steam and water drum, so as to facilitate renewing them from time to time. A longitudinal baffle in the steam and water drum ensures the steam passing from the top of the drum to the superheater tubes, and a similar longitudinal baffle is provided opposite the ends of the feed-heating tubes, so as to prevent the comparatively cold water passing directly from the feed-heating tubes into the downcomer water tubes. The uptake is divided by a longitudinal baffle which extends upwardly to the chimney, a damper being fitted in each passage which are so coupled that while both cannot be completely closed at the same time, either may be closed or partly or completely opened when the other is partly or completely opened. The illustration is in transverse section, *a* is the steam and water drum, *b*, *c* the two water drums, one on each side of the furnace *d* and connected by generator tubes, *e*, *f*, respectively with the steam drum *a*; *g* is the superheater and *h* the feed-water heater, g^1 and h^1 being longitudinal baffles in the steam and water drum *a*, one opposite the ends of the superheater tubes and extending upwardly to the top of the steam drum, and the other opposite the ends of the feed-water heater tubes. In order that the superheater and feed-water heater tubes *g*, *h* may be straight and yet meet the wall of the steam drum *a* in a radial direction, and also to avoid increasing unduly the width of the boiler while securing sufficient length of superheater and feed-heater tubes, the two banks of tubes are disposed as shown in the drawing, namely, with the collector g^0 of the superheater about as much above the center of the steam drum as the feed-water pocket or drum h^0 is below the center. With this disposition also and using straight tubes, the ends of the superheater tubes *g* are expanded into the wall of the steam drum (thickened locally as shown) about and above the normal water level in the steam drum, while the feed-heater tubes are expanded into the wall of the drum *a* about and below the normal water level. When it is desired to make provision for using either the whole boiler or either half only of the boiler at will, a plate *i* extending longitudinally above the steam and water drum *a* along the whole length of the boiler divides the uptake into two parts *j*, *k*, the furnace gases which traverse the tubes *e*, *g* passing upward through uptake *j*, and the gases which traverse the tubes *f*, *h* passing through uptake *k*. These uptakes are provided with dampers j^1, k^1 respectively, mounted to rotate upon horizontal axles, each provided with a quadrant rack *m*. These racks *m* are rotatable by means of pinions or worms *n* carried upon spindles *o* suitably journalled in brackets at the end of the boiler and rotatable by means of the hand wheels *p*. The damper axles have arms *q* rigid therewith, and these arms are coupled by means of a link *r*, which is connected pivotally with one arm and through a pin-and-slot connection *s*, *t* with the other arm. The link *r* and slot *t* are of such lengths that the dampers j^1, k^1 cannot both be completely closed at the same time, while they may be both completely open at the same time, or either of them partially or completely open, while the other is completely or partially closed.—"The Steamship."

THE NEW NICLAUSSE HIGH-DUTY MARINE-TYPE BOILER.

In a paper read before the Paris meeting of the Institution of Mechanical Engineers in July, Mr. Jules Niclausse sets forth the general features and latest improvements of the Niclausse boiler. In this boiler all the evaporating tubes are fitted at one end only into the headers, and a perfectly tight joint is assured by metal-to-metal conical joints. The other end is closed by a cap and is carried by a supporting plate. The removal of any tube is very easily and rapidly effected, so that a shut-down for any cause does not put the boiler out of service for more than a relatively short time. The

tubes being fixed at one end only, expansion or contraction takes place freely, and it will be seen from Fig. 1 that the old screwed-on lantern end has been suppressed, the tube being now solid-drawn throughout, with swellings to form the cones.

As shown in Fig. 1, each header is divided into two compartments by a vertical partition plate, separating the steam and currents. The current of water flowing through the front compartment of the header is distributed to each evaporating tube by an inner tube contained in the former. Windows cut in the header end of the evaporating tube enable the water to enter and the steam to depart in two distinct currents, so that positive circulation in only one, the correct, direction is ensured.

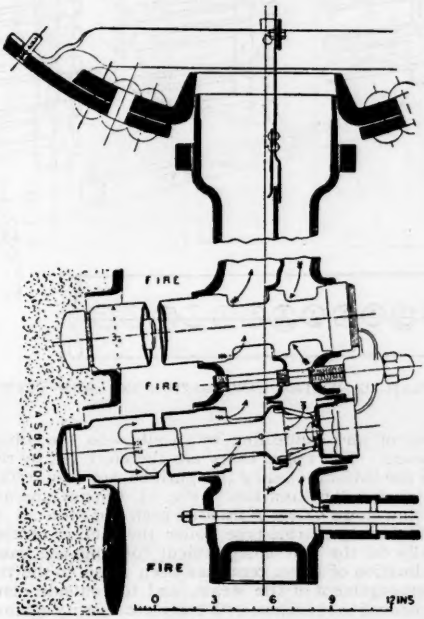


FIG. 1.—HEATER AND EVAPORATING TUBE ENDS.

The steam and water drums are divided into two compartments by a longitudinal diaphragm plate in prolongation of the vertical partitions in the headers, as shown in Fig. 2. The feed, after passing through a trough *C* wherein carbonates and other impurities are precipitated, and whence they are ejected by means of a blow-down valve *D*, enters at the front compartment, descends the vertical headers for a certain distance determined by a cross diaphragm *E*, passes into the upper evaporating tubes, and returns with the steam there produced into the back compartment of the drum, which consequently contains only hot and purified feed. The purified feed then descends by two tubes placed in front of the side walls, in the case of the high-duty boiler, Fig. 3, into a square horizontal header located longi-

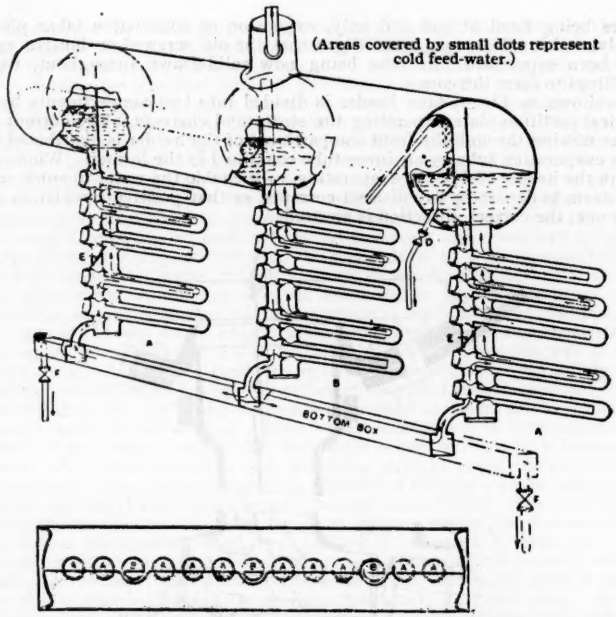


FIG. 2.—DIAGRAM OF WATER CIRCULATION IN LAND TYPE OF BOILER.

tudinally in front of, and connecting by an elbow to, the bottom of each of the vertical headers. The upper tubes are therefore fed by relatively cold feed water, and the bottom tubes by the purified hot feed. The horizontal header also serves as a "bottom box" (Fig. 2), whence impurities can also be rejected by blow-down valves *F* fitted at each end of it.

In the new high-duty marine-type boiler the section of the headers is increased, chiefly in the rear compartment forming the passage for the steam. An inclination of 15 per cent. has been given to the tubes in order to facilitate disengagement of the steam, and the outside diameter of the tubes has been reduced to 2¾ inches, with complete security against all forms of distress. This boiler is fitted with a feed-reheater, placed above the tubes, and the water circulates into this apparatus on the contraflow principle, that is, in the reverse direction to the hot gases. It has no superheater as usually arranged between the tubes in the land type, but is fitted with a new system of gas baffling, which doubles the length of the gas flow in the tube *faisceau*, ensuring improved utility and efficiency. This comprises plain open-ended tubes laid between the evaporating tubes, forming gas passages, as is shown in Fig. 3. This type of boiler has recently been tested by French naval experts with very satisfactory results.

The Niclausse mechanical stoker comprises fire-bars in short sections interlocking each other and carried in supporting bearers, which are given an intermittent to-and-fro motion, so that two adjacent bars always work in opposite directions. There is a momentary cessation between the movement backwards and forwards. The bar movement is effected by means of

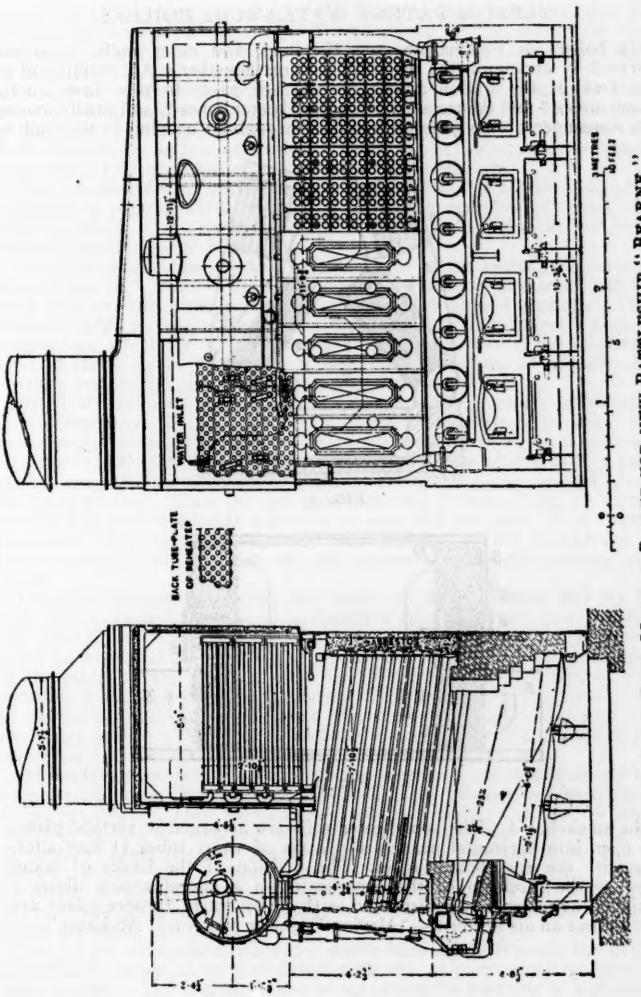


FIG. 3.—HIGH-DUTY MARINE BOILER FOR NEW BATTLESHIP "BEARNE."

a slowly rotating shaft mounted with hard steel cams, which engage with hard steel trip pieces mounted on bearer heads. The speed of the driving shaft can be varied from 1 to 6 revolutions per minute.—"The Shipbuilder."

YARROW PATENT WATER-TUBE BOILERS.

In boilers of the marine type, the inner and outer walls, 8, 8*a* are formed by arranging the water tubes close together. An opening 10 at the rear of the wall 8 allows the furnace gases to pass first among water tubes 3 and thence among the superheater tubes 7, and finally among the remainder of the watertubes 3 and through an opening in the wall 8*a*

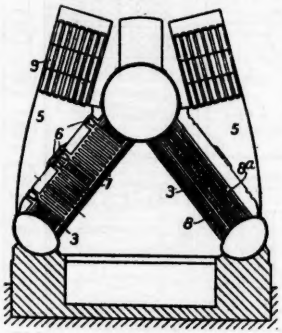


FIG. 1.

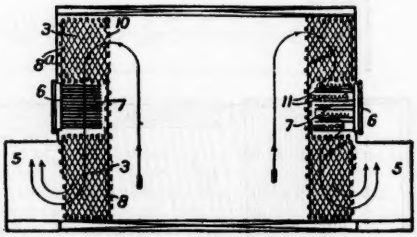


FIG. 2.

to the smokebox 5. The superheater coils are arranged in vertical planes and open into horizontal headers 6. Walls of water tubes 11 may alternate with the superheater tubes. The division of the banks of water tubes by the insertion of the superheater in a lateral recess allows a special downcomer to be dispensed with. The waste furnace gases are used to heat an air heater 9.—"Marine Engineer and Naval Architect."

SOME PROBLEMS CONNECTED WITH THE USE OF SUPERHEATED STEAM.

By P. J. Haler, B. Sc.; and A. H. Stuart, B. Sc.

The pressing need of economy of fuel and of obtaining cheap motive power has during recent years brought the subject of superheated steam very much to the front. Moreover, as the advantages claimed for it have

become more manifest, a very strong tendency has been exhibited to increase the degree of superheat. Temperatures of 700 degrees F. are today quite common, and it is confidently hoped in some quarters to reach 900 degrees F. in the near future.

The use of these high temperatures has confronted the designer with problems of an entirely new type, while he has been further handicapped by the fact that the expert on the testing side has so far only been able to offer totally inadequate data relating to the physical properties of metals under the action of steam at such degree of superheat.

It is now accepted as a general guiding principle that cast iron is quite unsuitable for parts which come in contact with superheated steam, the effect of which is to render the metal liable to failure, and at the same time to cause excessive corrosion.

The cause of the first of these effects is due to the recently discovered phenomenon of "growth" which certain metals (notably cast iron) exhibit when they are submitted to successive heat soakings and coolings. This property only becomes evident when the heating extends above a certain temperature, which for cast iron appears to be somewhere in the neighborhood of 700 degrees F. Hence it required the advent of superheated steam to lead to the discovery of this phenomenon.

Fig. 1 shows the results of some experiments in which micrometer measurements of the specimens were made after thirteen heatings, the latter being conducted in a muffle furnace, the temperature of which was recorded electrically. It will be seen that in the case of cast iron a very marked growth has taken place, a maximum length being reached about the tenth heating. Since the specimen was only 8 inches long, an extension of 0.15 mm. represents a growth of over 0.07 per cent. It is readily seen that unless ample provision is made for this growth *in addition to* that required by the ordinary thermal expansion, excessive stresses may result.

This phenomenon of growth has been studied in another way by M. Felix Robin (*vide* "Bulletin de la Société d'Encouragement pour l'Industrie Metallique"). By means of a special type of metallurgical microscope he has observed what he calls "the phenomenon of the apparition of the joints of the crystals." He has found that up to a certain temperature a metal may show a sharply defined crystalline structure, but if the temperature is raised above this limit the grains subdivide into secondary grains. "Growth" is probably the result of this change in the orientation of the metallic particles.

An investigation into the cause of the corrosion mentioned above has been carried on by Campbell and Glassford (*vide* "Revue de Metallurgie," December, 1912). They found that, in addition to the ordinary corrosion which is caused by saturated steam, the superheated variety, having the property of penetrating the graphite plates of the iron, causes the iron to corrode around each graphite plate. The consequence of this internal corrosion is readily seen. In this connection it has been shown that corrosion takes place materially slower in specimens in which the graphite plates are small.

One of the unexpected difficulties which have arisen through the use of superheated steam is in connection with the stop valve (large parallel slide valves). The best firms are in agreement in selecting a high-grade mild cast steel as the best available material for the valve case, but, unfortunately, this is unsuitable for the gate or disc, owing to its liability to corrosion (with consequent leakage).

For the valve seatings, therefore, an alloy has had to be obtained which would not oxidize under the action of superheated steam. The best material so far obtained is a nickel-copper alloy.

Having decided upon the material, the designer may either make the disc, etc., of the selected alloy, or use the latter for facing only. In this case he is forced to the adoption of the second alternative by the very

high price of the nickel alloy. Very serious trouble has been met with in connection with the available methods of fixing the alloy faces, in some cases unaccountable fracture having taken place, while in other cases the faces have worked loose.

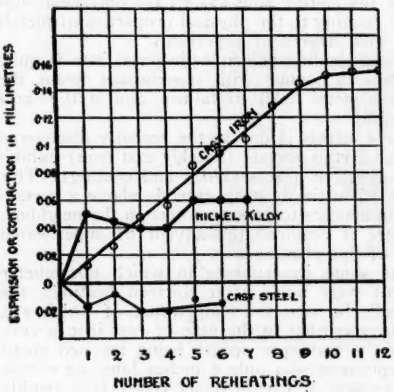


FIG. 1.

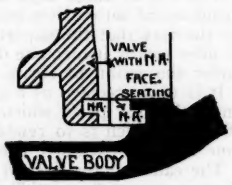
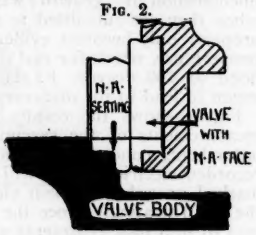


FIG. 2.



SUPERHEATED STEAM. FIG. 3.

Of the various methods which have been adopted, one of the commonest is to screw the ring of nickel alloy on to the disc. Another method which has been suggested is shown in Fig. 2. Here a channel is cut in the disc, and into the recess so formed, the nickel alloy face is pressed, and finally caulked.

Fig. 3 shows a third method, in which a thin tongue is left on the nickel alloy ring, and this is pressed into a corresponding recess in the disc. The tongue spreads out in consequence of the pressing, and thus fixes the ring in position.

A further reference to Fig. 1 will show that the nickel-copper alloy possesses the property of growing similar to that of iron, though to a smaller degree. Ordinary cast steel does not exhibit the property to any measurable extent. The graph marked "cast steel" in the diagram refers to a fine-grade rolled tool steel, and is of interest on account of its exhibiting the unusual property of shrinking.

There is little doubt that the trouble given by the nickel-alloy seatings mentioned above is partly due to the growth of the alloy, while the cast-steel casing fails to grow. The stresses set up on this account could be avoided to a large extent by submitting the nickel-alloy portion to successive heat soakings and coolings before taking off the final cut.

There is another point, however, which designers are apt to neglect. There appears to be no data available of the coefficients of linear expansion of the nickel-copper alloys now in use. In these circumstances a designer is apt to strike a mean between that of nickel and copper. This is a highly dangerous proceeding. The following table gives the coefficients of the metals concerned:

Metal.	Coefficient of Linear Expansion per Degree F.
Mild steel	0.0000065
Pure nickel	0.0000071
Pure copper	0.0000093

In a highly detailed investigation into the physical properties of the nickel steels (*vide* "Proceedings of the Institution of Mechanical Engineers," November, 1905, page 857), it has been shown that the coefficient of linear expansion of this alloy rapidly rises with the percentage of nickel. Thus nickel steel (1.2 per cent. Ni) has a coefficient of 0.0000067 (very little above that of mild steel), while the alloy which contains 19.9 per cent. of nickel has a coefficient of 0.0000108, which is approaching twice that of either steel or nickel.

No such detailed information is at hand referring to the nickel-copper alloys, but we are led to expect a similar rise in the coefficient by a determination on a single specimen of the alloy actually in use for a valve seating. This gave a value of 0.000017.

Comparing this coefficient with that of the cast steel of the valve casing, we see that there will be a very considerable differential expansion on the part of the nickel alloy, and unless this is allowed for excessive stresses may result.

Examining the various designs of valves in the light of this fact, it is clear that the stress will be chiefly exerted on the retaining flange. The flange may be forced outwards, or flow may take place in the material of the flange. In either case the loosening of the seating is the result. An analogous result is met with in the case of water pipes, the flanges of which are frequently rendered watertight by filling with lead and caulking. This method, however, is not possible when the pipes carry hot water, as the comparatively high expansion of the lead causes it to force itself out of the flange.—"Mechanical World."

TALBOT MARINE WATER-TUBE BOILER.

NOTE.—This boiler has been tested in some navy launches at the Navy Yard, Puget Sound. It is extremely compact and illustrates some novel principles of boiler design. This type of boiler, together with a special uniflow engine utilizing high pressure and high superheat, has been proposed for the operation of submarines in place of oil engines. This installation, though perhaps somewhat lighter than the oil engine, if it realizes the high efficiency claimed, could develop a I.H.P. on about .8 pound of oil per hour, whereas the Diesel will do this on about .6 pound of oil.

This steam installation may, however, secure somewhat greater reliability, which is greatly to be desired.—H. C. D.

(Description from "International Marine Engineering," September, 1914.)

An oil-fired water-tube boiler of exceptionally small size and weight per horsepower, for which remarkably high thermal efficiency is claimed, has been placed on the market by the Talbot Boiler Company of New York. The weight of a 100-horsepower boiler of this type, including all accessories, is only 5,000 pounds, or 50 pounds per horsepower, while the floor space occupied is only 3½ feet by 5 feet and the height 6½ feet. Automatic controlling devices regulate the supply of feed water to the boiler and of oil to the burners, making the boiler immediately responsive to the demands for steam.

The water enters the upper part of the boiler and the steam is discharged from the lower part, where the heating surface is directly in contact with the highest furnace temperatures. With the water and gases of combustion circulating in opposite directions two important advantages are obtained; first, the uptake gases are delivered at a much

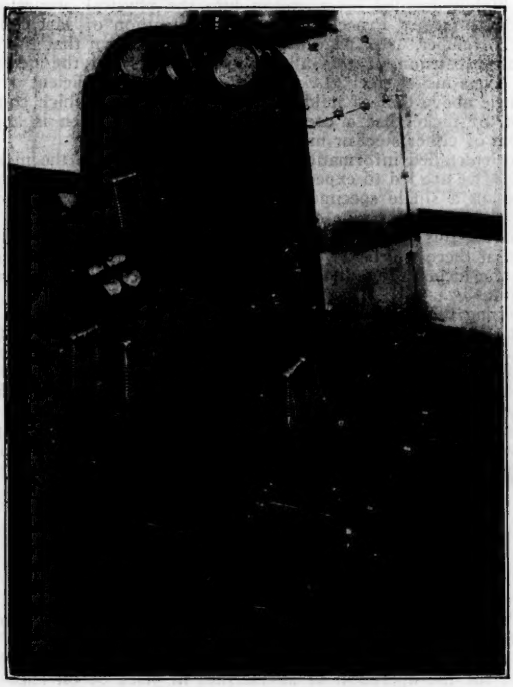


FIG. 1.—TALBOT WATER-TUBE BOILER.

lower temperature than that of the steam generated, thus enabling the boiler to be operated at a high rate of thermal efficiency, and second, the rapid circulation of water tends to eliminate the formation of scale in the tubes and keeps the tubes clean.

CONSTRUCTION.

The boiler consists of a number of specially-cored crucible-steel headers arranged horizontally one above the other, into each of which are screwed several groups of single-ended tubes also arranged horizontally. The free ends of the tubes are welded and flattened to permit the use of a wrench in removing or installing them. Inside the tubes, as shown in Fig. 3, are smaller circulating tubes leading into separate cored spaces or chambers in the header. The peculiar coring of the headers causes the water which enters at one end of the header to pass through the group of inner or circulating tubes leading from the first core or chamber and return through the outer tubes to the next core or chamber, which in turn connects the outer tubes of the first group with inner tubes of the next group of circulating tubes and so on, as the water passes successively through the groups of tubes in each header, beginning at the top and

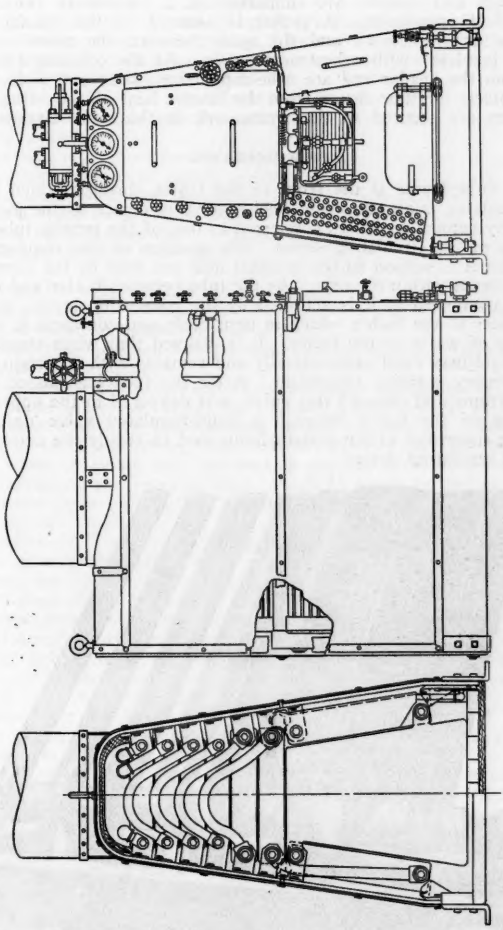


FIG. 2.—SIDE AND END VIEWS OF TALBOT BOILER.

finally issuing at the bottom as steam. In order to prevent the water from gravitating at once to the lower part of the boiler, each header is connected to the next header below it by a trap.

Two somewhat similar headers are arranged obliquely at the sides of the furnace, while at the back of the furnace is a crucible-steel wall so cored that the steam from the top of one of the side headers is carried through this wall to the bottom of the other side header, which is the last header in the series of circulation. This coring is so proportioned that a high velocity is maintained throughout during the operation of the boiler.

The tubes and headers are supported on a framework consisting of four vertical stanchions. A jacket is secured to the outside of the stanchions or framework and the space between the tubes and these panels is insulated with asbestos-magnesia. At the opposite end of the boiler from the header end are tube-supporting plates and a door frame which protects the tube sheets from the intense heat of the furnace. The tube sheets are secured to the framework in the same manner as the headers.

FEED REGULATOR.

On the door frame at the front of the boiler, through which the feed water circulates, is an automatic feed-regulating device of the piston type operated by compound levers connected to one of the nearby tubes in the last group of the circulating series. The position of this regulating tube is such that it is subject to the greatest heat not only of the furnace, but from the steam within the tube. As the tube becomes hotter and expands, the valve connected to it is actuated by the connecting levers, so that it admits water to the boiler, which in turn cools and contracts it, reducing the supply of water to the boiler. It is claimed that when steam enters, this valve adjusts itself automatically and remains with a certain opening under ordinary working conditions. After the feed has passed through the door frame and through this valve, it is delivered to the upper header at the top of the boiler through a hand-regulated valve designed to adjust the superheat within certain limits and to steady the action of the automatic regulating device.

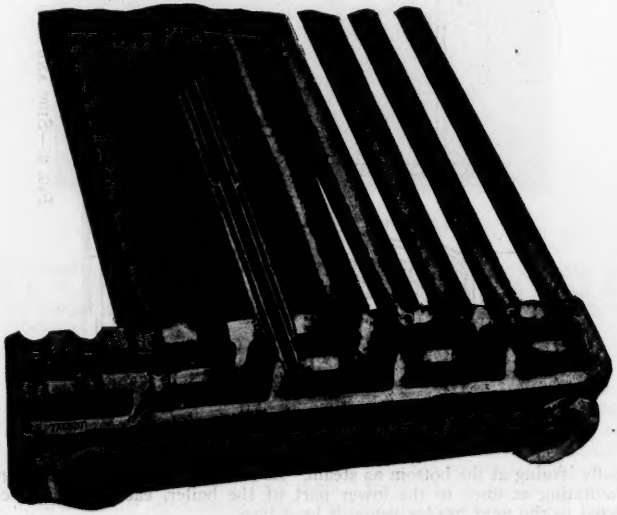


FIG. 3.—HEADER, SHOWING ARRANGEMENT OF TUBES.

An automatic safety device operated by the regulating tube is also provided which cuts off the oil to the burner when the heating surface of the boiler becomes overheated. The simple nature of the regulating devices on this boiler and the use of oil fuel make the boiler very easy to handle,

while the savings in weight and space, and the economy of fuel consumption, make the boiler particularly suited for marine work.

The following is an extract from "Power," April 1, 1913:

Following is the result of a two-hour evaporation test that was made with a Talbot boiler rated at 100 H.P.:

Water evaporated, pounds	7,446
Oil used, pounds	490
Average temperature of feed water, degrees F	97.4
Average temperature of steam, degrees F	390
Average temperature of oil, degrees F	65
Maximum stack temperature, degrees F	350
Minimum stack temperature, degrees F	265
Temperature of boiler room, degrees F	70

The calorific value of the crude oil used was 18,500 B.t.u per pound, and when corrected for moisture the test shows an evaporation of 17.31 pounds of water per pound of oil.

The following additional notes have been taken from information supplied by the manufacturers:

Advantages of High Circulation.—The rapid circulation in the Talbot type of boiler preserves the heating surface in two ways, as no scale forms in the tubes where the greatest heat is applied, they are prevented from burning by being kept clean. The extreme velocity carrying great quantities of water or steam over the heating surface prevents the tubes from being burned by the extreme heat, which in ordinary boilers drives the water away from the heating surface forming gas pockets between the water and the metal.

Durability of Tubes.—It is impossible to over-heat the tubes in the furnace of a Talbot boiler when in running order, no matter how hard or intense the fire may be, as long as water, of course, is admitted to the upper portion of the boiler.

Repairability.—These many advantages have been accomplished without sacrificing the repairability. All of the tubes may be readily renewed from the firing end of the boiler. The tubes are single-ended screwed into a crucible-steel header at the opposite end of the boiler, so that the flattened end of every tube is accessible after opening the tube door, facilitating the use of a wrench (a monkey wrench will do in the absence of the socket wrench furnished), so that the renewal of a tube is only a matter of a very few minutes.

Quick Steaming.—Any tube in a 100-H.P. boiler can be renewed (including the time of "blowing down" and "steaming up") in ten to twelve minutes' time. In the smaller sizes, such as are used for steam launches, tubes have been renewed and full speed resumed in three minutes' time. The boiler does not have to be cooled, nor does all of the pressure need to be blown down to make this repair. All the tubes are equally accessible, and there are no screwed pipe fittings in the fire, as the tubes are single-ended, the outer ends resting in a perforated sheet loosely fitting the tube nearest its end. This construction permits free expansion and contraction of all the tubes, thereby eliminating all expansion strains in the boiler, permitting it to be quickly steamed up without the usual strains and danger of leakage.

Connections.—We have stated that the water enters the top of the boiler, and that the steam is delivered from the lower portion, or that part of the heating surface next to the furnace. It is obvious that the water, unless prevented from doing so, will gravitate to that portion containing the steam. The water is prevented from gravitating by a series of traps; in fact each header is connected to the succeeding header below by one of these traps, so that each header full of tubes is some-

what similar to a separate boiler, except, of course, that the circulation is forced through certain fixed channels formed by the tubes, and the peculiar coring just described.

The Operation.—The operation of the Talbot boiler is substantially different from the ordinary boiler. As it will be seen, there is no water glass, nor are there gage cocks to determine the water level; in fact, there is no water level.

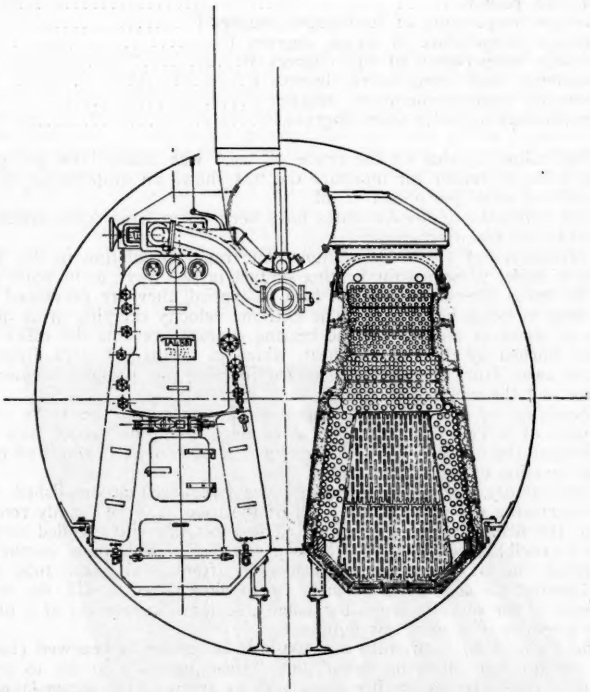


FIG. 4.—BOILER AS PROPOSED FOR A SUBMARINE.

Gages.—In a conspicuous space at the top of the boiler are arranged the gages, which include oil-pressure gage, feed-line pressure gage, and the steam gage, showing the pressure within the steam pipe at the delivery end of the boiler, and the boiler gage showing the pressure of the water before entering the top of the boiler (the inlet pressure). The resistance, or section through the tubes, may be determined by noting the difference between the pressures shown on these last two gages. The oil-pressure gage shows the pressure on the fuel-oil system, the burner of which forms a part of the oil-burning type of Talbot boiler.

Temperature Gage.—In addition to the gages just described, is the temperature gage, which is connected to the regulator tube, and registers its lineal expansion or travel, thereby showing the approximate temperature degrees Fahrenheit of the steam and of the regulator tube. The steam

temperature and tube temperature are always proportionate. This temperature gage serves the same function, and is more reliable than the water glass used in the ordinary boiler, because, in case of the latter, the glass frequently shows water when the water is really below the level shown, due to priming and other physical conditions, which are apparently impossible to overcome with the varying condition under which boilers must operate. This temperature gage shows accurately the water condition in all Talbot boilers. Thus if the temperature is high there is little water, and if the temperature is low too much water is being admitted. These conditions are automatically taken care of when the boiler is properly adjusted for operation. The adjustment being accomplished in two ways.

Regulator Adjustment.—The first adjustment is that of the relation between the tube and the valve, causing a greater or less opening in proportion to the temperature of the regulator tube, which indicates a greater or less temperature of steam being delivered. The second regulation is of the hand valve, which is quickly set to vary this temperature adjustment within certain limits. This valve is the only one handled or adjusted after the automatic regulator is once set; in fact, it even takes care of a change in load, varying from 25 to 100 per cent. without resetting. When the load is less than 25 per cent. it is necessary to partially close this valve, minimizing the duty on the automatic regulating device, which, if left to regulate the boiler without the quantity of admission of water being restricted through this hand valve, will maintain a "pendulum" action. We mean by this that the regulator will sway, permitting the boiler to periodically vary in temperature or pressure as regards the steam being discharged. The setting of the hand valve is easily accomplished as it is calibrated, so that once adjusted for an approximate load it is again easily set to the same adjustment for a similar load. This adjustment permits considerable varying of load without readjusting. If the hand valve is opened too wide the "pendulum" action will take place, and if it is closed down too far, the boiler will naturally become overheated for lack of water, as the automatic regulating valve cannot supply water even though wide open, as all of the water entering the boiler has to pass through these two valves. By setting this valve so that the "pendulum" action will be overcome, or at a point where it is nearly overcome, saturated steam will be delivered, while a varying degree of superheat can be maintained by further closing this hand valve, care being taken not to close all of the water off. The first time this hand valve is adjusted, the operator should wait for five or ten minutes to note the results, as considerable time is required in setting the regulator on a new boiler, as the action of the water and the expansion of the tube are not simultaneous. It is an easy matter, after once learning the operation of this regulating device, for anyone to handle the Talbot boiler, even though the operator's experience with boilers is limited.

Oil Cut-Off.—An automatic safety device is provided and operated by the regulator tube, so that a spring-loaded valve in the oil line is closed when the tube attains the temperature at which this valve is released. The tube releases the trip or trigger, which is adjustable for nearly any degree desired, preventing excessive superheat, and also preventing the heating surface of the boiler being destroyed, even though the supply of water is shut off from the boiler, as might occur in the event of the failure of the feed pump.

The simple nature of the regulator, as well as its strength and certainty of operation, have made running conditions easy even for amateurs. In one instance a steam launch has been operated frequently and for hours at a time by a seven-year-old boy. It is obvious that as the boiler is automatically regulated, and when oil is used as a fuel, little or no attention is required. The oil-burning Talbot boiler will run for long periods of time without the slightest attention. Its compact nature permits it to be in-

stalled in a vessel abeam of the engine in much the same manner as a surface condenser. The fore-and-aft space required being that of the boiler and the firing space, which also is useful in the removal of tubes when necessary. The weight of the boiler at the side of the engine has proved to be an easy matter to balance by fixed loads of a greater distance from the center of the ship. These comprising an auxiliary feed pump, hot well, and an oil-burner equipment, tools, etc.

The compactness, weight and great efficiency has proved this a popular type where it has been introduced. It is available for power purposes, which have heretofore been necessarily supplied with internal-combustion engines. The space and weight required by a Talbot boiler and steam engine being less than that of the gas engine, while the cost of operation is very much less than even gas engines using similar fuel, such as the Diesel type.

SUBMARINES.

DEFENCE AGAINST SUBMARINE MINES.

Ever since the great sea Powers have used automatic torpedoes, mines and submarines, means of destroying them have been sought. At the same time that ships for planting them have been developed, others have developed ships for destroying them. To render an enemy's mines ineffective is a problem of which there are several theoretical solutions.

The first, applied in the most recent armored ships, is to protect the hull against the effects of an explosion. If this could be done with the larger ships, it would mean practically the end of automatic torpedoes, for the smallest ships are practically immune from damage from them, owing to their small draught. However, for a long time to come submarine mines will probably remain powerful engines of war. There is then only one practical defence applicable to these mines—to destroy them. Naturally, the first consideration is to learn where they are; to observe if the enemy has planted only one line or but a few lines of these mines. If they were not seen planted, we can only surmise their number and position, which would be most probably perpendicular, or nearly so, to the axis of the channel desired to be blocked.

A good method consists in countermining or in exploding mines in the midst of the mine field. These countermines should carry a charge of at least 200 pounds of gun cotton, so that the concussion shall be strong enough to be effective at a relatively great distance, setting off the sensitive percussion mechanisms of the mines, or causing them to explode sympathetically. If they do not explode, experience has shown that the explosion of the countermine has at least the effect of opening the metallic cases of the mines, allowing the entrance of water through the loosened rivets, finally causing all of them within a certain radius to sink, rendering them ineffective. The English, German and French navies have countermines. In Germany these are called "clearing torpedoes"; they are fired by electricity at a distance. It is easily seen that this is the most rapid way and perhaps the most effective means of clearing a passage. It offers the inconvenience, however, if used over an extended area, of involving the use of considerable explosive, and it is without doubt for this reason that it was employed so seldom during the last war, wherein the struggle against mines and submarines played an important part. Besides the "clearing mines," the German navy possesses the necessary material for dragging channels, or wider bodies of water if necessary.

If there is any reason for supposing that the enemy has been able to scatter mines in front of one of our ports, dragging machines should precede all submarines from the port to clear the passage of obstacles. These ships can be ordinary tugs or simple launches. The employing of torpedo boats for this service is a mistake, because of the difficulty in maintaining the necessary slow speed. But the risk to the tugs, which is great, would be diminished if use were made of boats built expressly for the purpose with a draught of about 2 feet, with a large, flat bottom, like the ordinary barge, so as to retain great stability. Vice Admiral Fournier, of the French navy, submits that a non-submersible vessel could be obtained by filling all compartments with some light substance that increases in volume on being wetted, such as asbestos or cellulose.—"Mechanical World."

BATTLESHIPS AND SUBMARINE ATTACK.

Although the paper on "The Protection of Battleships against Submarine Attack," read at the meeting of the Institution of Naval Architects at Newcastle-on-Tyne last week by Sir John Biles, was admittedly of a stop-gap nature, it formed an interesting and opportune subject in view of the questions raised by Sir Percy Scott in his letter to "The Times" on June 5th, dealing with the submarine menace. It is, in fact, difficult to separate the two contributions, though that of Sir John Biles dealt more particularly with structural questions than with the tactical points on which Sir Percy Scott based his arguments. Sir John Biles' paper briefly raised four main points, which, slightly transposed, were: Whether the submarine menace was sufficient to justify armoring the under-water portions of a ship to a much greater extent than is done at present, and, if so, whether 4-inch armor would form sufficient protection; or was the menace sufficient to justify the construction of smaller and slower battleships carrying six guns only instead of eight or ten, and would armor be of sufficient value to justify a modification in the form of ship, which, although facilitating the manufacture of the armor, would offer greater resistance than the ordinary form? In the course of the subsequent discussion answers to these queries were afforded by the statesman, the naval officer, and the ship constructor to a varying degree. The fourth question was immediately shattered by Mr. Charles Ellis, who expressed the opinion that just as armor-plate makers had already been forced to provide shapes which were considered impossible only a few years ago, so they would be able to furnish in future armor of any shape likely to be required. This statement really only elaborated the already well-known fact that shaped belt armor of considerable depth and curvature, giving a perfectly fair contour to the curved outline of a warship's hull has been extensively fitted in recent years, and in all armor-plate erecting shops, wherein the fairing of the armor with all the skill of the mold-room is already accomplished, are to be found men who are certainly capable of carrying existing practice to a much greater degree of perfection. Lord Brassey, was disinclined to overlook the arguments in favor of the same total armament carried in more and smaller vessels, a view that Sir Philip Watts contradicted in his remarks. He alone categorically answered all the four questions propounded, and his views are of great interest, as he stated plainly that up to the present time the submarine menace had not been considered of sufficient importance to justify armor protection on the bottom of a ship; but he thought that 4-inch armor, if supported by suitable internal subdivision, would afford sufficient protection against torpedoes. Sir Reginald Custance confined himself to the

war value of the Whitehead torpedo, and, basing nearly all his remarks on the experience of the Russo-Japanese war, regarded the torpedo as a very inferior weapon to the gun, and one on which too much reliance should not be placed. He left the points raised in the paper unanswered except by deduction. Professor Hovgaard's contribution to the discussion dealt mainly with the constructional possibilities in protecting a vessel's bottom, and pointed out that to do so effectually against external explosions a resistance greater than that afforded by the inertia of the water must be provided. For a big charge and a depth of 20 feet this would seem almost impossible.

Hardly had this discussion terminated, which it really did with a strong expression of opinion that the Admiralty should undertake experiments to determine whether armoring the bottom of battleships was advisable, than Sir Percy Scott's lengthy reply to his many critics appeared in "The Times" on July 10th. Neither they nor he appear to have considered—or, at all events, have not referred to—the possibility of so constructing battleships as to render them safer against torpedo attack than they are at present It is also curious that this sudden phase of thought over the dangers to a vessel of a torpedo striking her should have led to so much discussion without anyone having pointed out that it is quite immaterial whether the torpedo is fired from a surface craft or a submarine, and that the danger from the former is also a very serious matter indeed with modern long-range torpedoes, and one in which, as far as destroyers are concerned, there is already a considerable amount of war experience. Certainly, hitherto the whole argument has had nothing to do with craft other than submarines, but at the back of the whole question lies the capability of the structure of the modern battleship to withstand torpedo attack. The matter has been debated every year since the introduction of the automobile torpedo, nearly forty years ago. Put on 4-inch armor and increase the subdivision—Sir Philip Watts suggested even thicker armor if necessary—and what will be the result; only to increase the diameter, and with it the bursting of the torpedo? What has been the history of the gun? Till Sir Percy Scott led the way in target practice it is doubtful if the percentage of hits with it in war time would have been any better than it was with the torpedo in the Russo-Japanese war. In fact, in the Spanish-American war it was vastly less. The experience in the Sea of Japan with 16-inch and 18-inch torpedoes was sufficient seriously to affect the internal protection and subdivision of the entire Dreadnought type, and this was before the introduction of the 21-inch torpedo with its hot-air attachment and gyroscopic control, and what Scott did for the accuracy of the gun these have accomplished for the torpedo. Many officers seem to think that the menace of destroyers is a vastly greater deterrent than that of submarines which are relatively slow, and there is no doubt that with the range and accuracy of its existing weapons the surface boat is a very formidable antagonist to the big ship. It is, however, a visible foe; but, on the other hand, it is a habitable one. These conditions are largely reversed in the case of the submarine, which by no means possesses the sea-keeping capabilities of the destroyer. Why, then, was the risk of a successful destroyer attack, *i. e.*, if a torpedo got home, treated so lightly? Why has the destroyer program been reduced in England and France and the submarine flotilla increased? The fact is, as we have stated before, that to a considerable extent warship design at the moment is in a state of flux, and even among naval officers there is a very wide diversity of opinion as to the relative value of various types. There always has been diversity, if one accepts the views of extremist schools, whose arguments have generally resulted in chaotic blunders being made, but at the present time the difficulty of accurately apportioning relative values to probable efficiencies of various weapons or types of ship in war time is one of supreme difficulty, and is, moreover, quite outside

the sphere of a naval architect's work when the users themselves find it difficult to make up their minds. Armor is put on a ship in positions liable to attack by gun fire in order to force an enemy to use a less dangerous projectile than he otherwise would. The limitations to increase of size in torpedoes are less than in the case of artillery, and consequently a more dangerous projectile can be introduced with relatively small difficulty in order to maintain the superiority of the attack. To this the only real answer that can be made is a radical change of type of big ships, rather than the piling on of defensive properties. Effectively to armor the under-water sides of a vessel of the type of the *King George V* would involve reducing the main water-line belt from 12 inches to 10 inches, and the upper portion of the side from 9 inches to 7 inches and 5 inches, while at the same time it would require an addition to the displacement of some 2,000 tons. Seeing that already there are some 5,000 odd tons of armor in such a vessel, are we really to consider a proportion of 7,000 tons of armor in a vessel of 25,000? True, 28 per cent. of the displacement is not the maximum that has been adopted; in the old *Nile* and *Trafalgar* it was about 33 per cent., but the conditions were entirely different. That heavier plating will likely be adopted in future is quite another matter. Small, thick plates are ill adapted for withstanding gaseous pressures on account of the difficulty of adequately joining them; the necessity for providing against the intense local percussion caused by a projectile is absent in the case of the torpedo, where the effect is more widely distributed. Actual armor of the present type is therefore far less likely to be adopted than steel plates perhaps 1½ inches or 2 inches thick, worked in such a fashion that the joints are as remote as possible from one another, and are reinforced on the inside to a much more elaborate extent than is at present provided for above water work. But when this is done the 21-inch torpedo with its 330 pounds charge will become the 24-inch type carrying 500 pounds, and the problem will again require solution. That Sir Percy Scott had this in view when he started to stir up discussion seems very certain; but no one pointed out this fact during the discussion on Professor Biles' paper. Even with armor and subdivision below water the attack must remain superior to the defence, for the simple reason that all that is necessary is to fire two tubes instead of one. Just as in volley firing it is possible simultaneously to put several 12-inch shells into the space of a tennis court at long ranges, a submarine that can rely on hitting with one tube can almost certainly hit with two, and no defence will withstand such an impact. Naturally, this does not relieve naval architects of the onus of providing all the protection possible to the hull, though obviously the best defence is the destruction of the submarine. How that is to be accomplished is extremely difficult to see, because the type is tending more and more to merge into the sea-going destroyer with submersible capabilities, and of a size and speed that will render it not only much more habitable but capable of undertaking work at present far beyond its power.

Both Sir Percy Scott and Sir John Biles are to be congratulated on the extensive interest and discussion that their contributions to naval literature have aroused. Few, if any, letters of recent date have created such widespread comment or revealed such a divergence of opinion combined with the realization of the seriousness of the submarine menace as did Sir Percy Scott's, while Sir John Biles, in pointing out the sacrifices that require to be made in protecting vessels against torpedo attack seems to have succeeded in showing, as much by his own paper as in the course of the discussion that followed it, that the question of the size of battleships, the degree of danger to which they will be exposed in war time, and the relative proportion of the displacement which should be devoted to defence, all remain today as definitely unanswerable as they have ever been.—"The Engineer."

RADIO.

THE CAPACITY OF RADIOTELEGRAPHIC AERIALS.*

By Professor G. W. O. Howe, M. Sc.

The capacity considered in this paper is the actual static capacity, and not the equivalent capacity, of the antenna considered as part of an oscillatory circuit. The accurate calculation of the capacity of a multiple-wire horizontal aerial with its leading-down wires would be a difficult mathematical problem, quite unwarranted by the practical requirements of radiotelegraphy.

When raised to a potential above or below that of the earth, the charge is distributed over the antenna in a way which is not easy to calculate, but which must be such that all parts of the antenna are at the same potential. If the antenna were made up of a great number of short pieces placed end to end, but insulated from each other, it would be possible to distribute the charge uniformly; but the potential would then vary from point to point in a way which is easily calculated. If now we assume that all the separate pieces of wire are connected, electricity will flow from points of high to points of low potential until the potential is everywhere the same. The assumption made in developing the various formulae is that this final uniform potential is equal to the average value of the potential when the charge was uniformly distributed. This is only approximately correct; but the accuracy is more than sufficient for all practical purposes. This method has been applied to antennae of all the types usually employed, and formulae have been established for each type. A large number of numerical examples have been worked out, and the results are given in tables and curves, so that the capacity of any antenna can be read off directly from its dimensions. The corrections due to the leading-down wires and to the proximity of the earth are fully considered, and examples given showing the application of the formulae to antennae of any type.

Formulae for the calculation of the capacity of antennae have recently been published by Pedersen ("Jahrbuch der Drahtlosen Telegraphie," vii. 4, p. 434) and Louis Cohen ("Electrician," February 14 and 21, 1913). When applied to the experimental results quoted by Cohen, the formulae developed in this paper give closer agreement than do the formulae given by Cohen, although some of his results can hardly be reconciled with the given data.—"Mechanical World."

*Abstract of a paper read before the British Association for the Advancement of Science.

ORDNANCE.

Correctors for Sighting Gear of Heavy Ordnance. "Engineering," Aug. 7, 1914.—This paper illustrates and describes correctors for temperatures and nozzle velocity, and for lateral movement of shot.

Armament of the Spanish Battleship "Espana." "Engineering," July 31, 1914.—This paper fully describes in detail the armament, turret mechanisms and construction on this vessel. As this vessel is being constructed under directions of Armstrong Brown & Vickers, the details may be taken to indicate late developments employed in the English service. The description in this article is complete and fully illustrated.

NAVAL VESSELS.

UNITED STATES.

UNITED STATES NAVAL VESSELS UNDER CONSTRUCTION.

DEGREE OF COMPLETION.

No.	Vessel.	Building yard.	Engines.	No. shafts.	Speed, knots.	Percentage machinery completed 1914.		Per ct. Hull com. Nov. 1, 1914.
						Oct. 1	Nov. 1	
	BATTLESHIPS:							
36	*Nevada*	Fore River S. Co.	Curtis turbine	2	20.5	82.63	*80.80	77.0
37	*Oklahoma*	New York S. Co.	Reciprocating	2	20.5	84.12	85.92	79.3
38	*Pennsylvania*	Newport News Co.	Cur. trb. grd. cr.	4	21	40.31	42.59	58.3
39	*Arizona*	Navy Yard, N. Y.	Pars. trb. grd. cr.	4	21	16.06	20.11	36.8
	DESTROYERS:							
45	*Downes*	New York S. Co.	Curtis trb. & rec.	2	29	96.83	96.82	95.3
51	*O'Brien*	Wm. Cramp & Sons	Cramp trb. & rec.	2	29	87.55	90.91	88.4
52	*Nicholson*	Wm. Cramp & Sons.	Cramp trb. & rec.	2	29	82.48	84.85	86.5
53	*Winslow*	Wm. Cramp & Sons.	Cramp trb. & rec.	2	29	77.64	81.41	82.3
55	*Cushing*	Fore River S. Co.	Curtis trb. grd. cr.	2	29	71.32	77.16	73.7
56	*Ericsson*	New York S. Co.	Pars. trb. & rec.	2	29	82.76	84.97	87.4
57	*Tucker*	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	24.43	25.57	18.8
58	*Conyngham*	Wm. Cramp & Sons	Pars. trb. grd. cr.	2	29.5	23.25	27.79	39.5
59	*Porter*	Wm. Cramp & Sons.	Pars. trb. grd. cr.	2	29.5	21.37	26.23	29.5
60	*Wadsworth*	Bath Iron Works.	Pars. trb. gearing.	2	30	64.04	70.11	66.4
61	*Jacob Jones*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	39.51	44.29	33.7
62	*Wainwright*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	41.17	46.01	33.4
	FUEL SHIPS:							
13	*Kanawha*	Navy Yard, Mare Isl'd.	Reciprocating	2	14	70.90	73.10	...
14	*Maumee*	Navy Yard, Mare Isl'd.	Diesel	2	14	31.00	40.26	...
	SUBMARINES:							
31	*G-3*	Navy Yard, N. Y.	Diesel-Sulzer	2	14	82.50	82.50	85.7
38	*K-7*	Union Iron Works	Diesel	2	14	100.00	100.00	98.1
39	*K-8*	Union Iron Works	Diesel	2	14	100.00	100.00	98.1
40	*L-1*	Fore River S. Co.	Diesel	2	14	87.22	90.20	67.4
41	*L-2*	Fore River S. Co.	Diesel	2	14	86.94	88.58	66.2
42	*L-3*	Fore River S. Co.	Diesel	2	14	86.21	88.05	66.1
43	*L-4*	Fore River S. Co.	Diesel	2	14	86.57	89.50	65.7
44	*L-5*	Lake T. B. Co.	Diesel	2	14	2.05	3.09	41.2
45	*L-6*	Lake T. B. Co.	Diesel	2	14	1.51	3.09	41.7
46	*L-7*	Lake T. B. Co.	Diesel	2	14	1.51	3.09	39.7
47	*M-1*	Fore River S. Co.	Diesel	2	14	81.86	83.21	50.6
48	*L-8*	Navy Yard Portsmouth.	Diesel	2	14	...	...	...
49	*L-9*	Fore River S. Co.	Diesel	2	14	31.57	49.37	24.9
50	*L-10*	Fore River S. Co.	Diesel	2	14	17.43	38.21	23.8
51	*L-11*	Fore River S. Co.	Diesel	2	14	...	8.77	11.2
	SUBMARINE TENDERS:							
1	*Fulton*	Fore River S. Co.	Diesel	1	12.25	96.44	97.31	97.8
2	*Bushnell*	Seattle Con. & D. D. Co.	Parsons trb. with gearing.	1	14	37.55	43.83	71.9
	DESTROYER TENDER:							
2	*Melville*	New York S. Co.	Parsons turbine with gearing.	1	15	50.23	55.94	70.2
	TRANSPORT:							
1	.....	Navy Yard, Phila.	Reciprocating	2	14	...	...	2.5
	SUPPLY SHIP:							
1	.....	Navy Yard, Boston.	Reciprocating	2	14	.32	.45	...
	TUGS:							
	Arapaho	Seattle Con. & D. D. Co.	Reciprocating	1	...	99.00	99.18	100
	Mohave	Seattle Con. & D. D. Co.	Reciprocating	1	...	98.21	99.06	100
	Tillamook	Seattle Con. & D. D. Co.	Reciprocating	1	...	96.90	98.64	100
	Oil Barges 8 and *9*.	Navy Yard, Mare Isl'd.	Reciprocating	1	...	15.40	22.10	100

* Reduction due to changes in machinery

Delivery of tugs has been authorized, Navy Yard Puget Sound.
Delivery of submarine *K-7* and *K-8* has been authorized, Navy Yard, Mare Island.

PROPELLING MACHINERY OF THE NEVADA.

The propelling machinery of the United States battleship *Nevada*, whose launch at the Fore River shipyard was recorded in our last issue, consists of an improved type of Curtis turbines, placed in four watertight compartments, arranged for twin screws. These turbines are designed to develop 26,500 shaft horsepower at 222 revolutions per minute. Each line of shafting is driven by a high-pressure turbine in the forward compartment, and a low-pressure turbine in the after compartment. Each high-pressure turbine is connected to its low-pressure unit by a 28-inch diameter exhaust pipe. In the after end of each low-pressure turbine there is built in a reversing turbine which exhausts through the common exhaust pipe to the condenser.

On the forward end of each high-pressure turbine shaft there is located a cruising turbine with reduction gear. These cruising turbines are designed to develop 2,750 horsepower at 3,200 revolutions per minute. The reduction gear has a ratio of 23.3 to 1, and thus drives the main propeller shaft at 137 revolutions per minute, which corresponds to a cruising speed of 13½ knots. The reduction gear is connected to the main turbine shaft by means of a clutch easily operated from the working platform. The main bearings and horseshoes for thrust bearings are provided with forced lubrication and water service.

The auxiliaries, consisting of condenser, air pumps, feed tanks, main circulating pumps, feed-water heaters, etc., are located in the engine rooms. The condenser and air pumps are designed to maintain, under full-power condition, a vacuum of 93 per cent. of absolute.

Arranged forward of the engine rooms are three firerooms, each containing four water-tube boilers of the Yarrow type, designed for oil burning by mechanical atomization in the burners. The boilers are designed for a pressure of 295 pounds gage, which drops to 265 pounds gage at the main turbines.

The fuel-oil system consists of the necessary piping, together with pumps, heaters, etc., each boiler being fitted with an emergency automatic shut-down valve in case any breaks in the fuel-oil piping should occur.

The air for combustion is furnished by forced-draft blowers, discharging air into the firerooms, which are of closed stoke-hold type. The blowers are designed to maintain the maximum rate of combustion, the number of revolutions not exceeding 1,050 per minute.

The machinery of the *Nevada* is noteworthy in that it is the first installation of high-speed geared turbines for cruising purposes on a United States battleship, and because of the opportunity it affords for comparison with a sister ship propelled by reciprocating engines.—"International Marine Engineering."

32,000-TON BATTLESHIPS.

Orders which have been placed with the Newport News Shipbuilding Company and with the New York Shipbuilding Company provide for two 32,000-ton battleships for the United States Government. Development in the size of battleships has been remarkable, and it is apparent that there is no immediate prospect of a return to Dreadnoughts of smaller size. It is interesting to observe the trend of warship design with the different maritime Powers. In the *Queen Elizabeths* Great Britain exhibited the desire for increase in speed at the sacrifice of number of guns; the battleships being completed by Russia in the Baltic display the same ten-

dency. In the latter vessels 23 knots is guaranteed, whilst probably 25 knots will be obtained by the *Queen Elizabeths*. The Italian constructors in the *Count de Cavour* class sacrificed armor protection for number of guns, thirteen 12-inch guns being mounted, whilst the main armor belt is only 10 inches thick. The United States have held to the principles of fair speed, powerful armament and admirable protection. In the *Pennsylvania*, their 31,000-ton battleship now under construction, twelve 14-inch guns are being mounted behind armor 18 inches in thickness and placed in groups of three in four barbettes. The main armor belt is 14 inches thick. Elaborate internal protection is also afforded so as to confine the effect of bursting shells. The high qualities of offence and defence which these ships possess can only be provided for at the expense of either speed or displacement. No other naval Power has built battleships approaching 32,000 tons displacement, and the Americans are satisfied that when the group of heavy ships is completed they will have a division of ships which cannot be matched by any navy of the world.

U. S. A. NAVAL SHIPBUILDING.

The Newport News yard sent in the lowest tender for the battleships referred to in the preceding note, the price being £1,439,000 for hull and machinery, with alternative prices of £1,430,000 and £1,423,000 for a vessel with modified machinery. The New York Navy Yard's estimate was £1,431,060, with an alternative price of £1,398,570 for a battleship with electric propulsion—an innovation presumably following the recent trials of the *Jupiter*. It will be seen, moreover, that the Government yard underbid the Newport News Company, but whether the work would have cost less in the end is another question; there is not the same necessity for accurate estimates in State work. Both the Fore River and Cramp yards were left out of the work, and it is anticipated that these two will compete very keenly for the destroyers, tenders for which will be asked very soon. Although these battleships are about 600 tons greater displacement than the *Pennsylvania*, the Newport News price was nearly £30,000 lower than their price for the latter ship, which, by the way, they are building. The following are the dimensions of the battleships: Length overall, 624 feet; length b.p., 600 feet; breadth, extreme, 97 feet 4½ inches; draught, 30 feet; speed, 21 knots. Main batteries: Twelve 14-inch guns and four submerged torpedo tubes; torpedo defence battery; twenty-two 5-inch rapid-firing guns; the ships to be heavily armored, propelled by turbines, and fitted with oil-burning boilers of the water-tube type.

AUSTRIA-HUNGARY.

SUBMARINES FOR THE AUSTRO-HUNGARIAN NAVY.

The latest additions to the submersible craft of the Austro-Hungarian Navy are represented in the two boats *U III* and *U IV*, built at the Germania Yard, Kiel, of Messrs. Fried, Krupp, Ltd. These boats have an extreme length of 142 feet, a breadth of 12 feet 4 inches and a draught (surface) of 9 feet 8 inches. They have an under-water displacement of 300 tons and a surface displacement of 235 tons. The vessels have a double hull, the inside hull being a cigar-shaped watertight body having a structural strength calculated to resist the hydraulic pressure corresponding to a depth of 165 feet. This inner hull is shown, and a view of

the first of these two boats taken shortly after launching is also given. The watertight hull is formed of nine circular welded sections, three of which, amidships, are cylindrical, the others, fore and aft, being slightly conical. The hull is subdivided by means of bulkheads into several watertight compartments. The bow section contains the torpedo armament and accessories; the next section is occupied by the crew and storeroom for electrical batteries, and contains also a galley, with electrical cooking range, and lavatory accommodation. The inner ballast tanks are situated amidships, and just below the conning tower is placed the steering gear for the two pairs of diving rudders. The engine room contains internal-combustion machinery and electric motors, whilst the last watertight compartment aft is reserved for another battery of accumulators. The outside hull does not differ much in shape from that of an ordinary torpedo boat, and is so designed in order to give the boat good sea-going qualities. A weather deck extends throughout almost the whole length of the ship, and can accommodate the crew when the boat is traveling on the surface. Between the deck platform and the inside hull all the kerosene and most of the water-ballast pipes are fitted. The conning tower, situated amidships, is framed of strong nickel-steel plates capable of resisting the attack of small guns. It is fitted with two periscopes, and all the appliances necessary to control the ship in action.

The only opening which gives access to the vessel is placed immediately above the conning tower. Communication between the conning turret and the steering gear below is effected by voice pipes. Aft of the conning tower is a conning platform for surface navigation. The tower is enclosed in a structure, designed on shipshaped lines, intended to diminish the resistance met when traveling under water. These two submersibles are propelled by two two-cycle heavy-oil engines, aggregating 600 H.P., for surface navigation. Two electric motors, designed to develop 320 H.P., are used for propulsion when the boat is submerged. The motors operate two reversible screws. The engine-room outfit of the new submarines comprises two main and one auxiliary motor-driven bilge pumps, two hand-worked bilge pumps for exhausting bilge and ballast water, air compressors and all accessories.

A particular feature of German submarine naval policy is the provision for salving appliances. These, in a way, have preceded the construction of submarine craft. This feature is also emphasized in these boats. They carry a safety keel weighing 5 tons, which can be detached by working a very simple gear, merely by the movement of a handle. By emptying the ballast tanks the boat can be floated in 1½ minutes. Several appliances have been fitted to purify vitiated air, and thus prolong the stay under water, so that the liability to accident is greatly minimized. Air connections are fitted on the outside plating which, under certain conditions, would allow communication to be made with the atmosphere. A buoy carried on deck can be unfastened from the inside of the hull in order that a telephonic connection can be established with a rescuing crew. Each boat is fitted with two 18-inch Whitehead torpedo tubes, and carries a supply of three torpedoes. The surface speed at trials was 12 knots, but it is anticipated that it will be surpassed in deep-water trial; the submerged speed is 8.6 knots. At an economic speed of 10 knots the radius of action is given as 1,200 miles above water and 60 miles submerged, the speed in the latter case being 6 knots.

The first boat, which underwent her trials in the Eckerfoerde Bay, was first of all submerged to the greatest intended depth—75 feet—in order to test watertightness, and remained two hours under water with 25 hands on board. After the trial the boat was floated in 1½ minutes by exhausting ballast water. The performance of this type of ship is responsible in a large measure for the increasing favor with which the sea-going torpedo boat is held in Germany.

AUSTRIAN DREADNOUGHTS.

The latest Austrian battleship of the "A" class to be delivered is the *Prinz Eugen,* built by the Stabilimento Tecnico, Triestino, who also constructed two of her sister ships, the *Tegetthoff* and the *Viribus Unitis.* The remaining vessel of this class was launched in January last by the Cantiere Danubuis, Fiume.

The chief dimensions of these vessels are:

Length (water line), feet and inches	495 4
Length (over all), feet and inches	524 9
Beam, feet and inches	89 6
Draught (mean), feet and inches	26 8
Displacement, tons	21,370

On her 24 hours' trial the *Prinz Eugen* maintained an average speed of 20.8 knots, and on the measured mile 21.3 knots, the former figures for the *Viribus Unitis* being 20.1. These Dreadnoughts are propelled by Parsons turbines of 25,000 B.H.P., and have 12 Yarrow water-tube boilers. Their full complement, including officers, is 1,000 men.

The armor is of special chrome-nickel steel. The *Prinz Eugen* has a complete belt about 15 inches wide which is 11 inches thick amidships and 4.7 inches at her fore and aft extremities. The following information is of interest:

Armored deck (maximum)	2½ in.
Armor, big guns (maximum)	11 in.
Armament	12—12 in. (45 cal.)
"	12—5.9 in. (50 cal.)
"	18—11 pr.
"	2—3 pr.
"	2 maxims
Torpedo tubes under water	6 (*Viribus Unitis* 4)
Fuel capacity (normal)	900 tons.
Fuel capacity (maximum)	2,000 tons.
Broadside fire of main guns	11,770 lbs.

The total cost of the construction of the vessel is estimated at £2,530,000, and she has taken nearly two and a half years to complete.—"Shipbuilding and Shipping Record."

JAPAN.

NEW JAPANESE DESTROYERS.

The building of 10 destroyers to be used in the present war was approved by the Japanese Diet which was summoned in September to consider the War Budget. The total sum of money to be spent for the ships is estimated to be £1,100,000. One vessel will be built at each of the following Government yards and the orders have already been placed with them: Yokosuka, Kure, Sasebo and Maizuru. Among the private yards, two will be built at the Mitsubishi Nagasaki Ship yard, two at the Kawasaki Ship yard, Kobe, and one each at the Osaka Ironworks, Osaka, and the Oraga Dock yard, near Yokosuka. These destroyers are said to be of the same type, with some improvement in details, as the *Sakura* class, the particulars of which are as follows: Length, o.a., 274 feet; length, b.p.,

260 feet; breadth, extreme, 24 feet; depth, molded, 15 feet 3 inches; draught, 7 feet 4 inches; displacement, 605 tons; horsepower, 9,500; speed, 30 knots; armament, one 4.7-inch, four 3-inch and four torpedo tubes.

These vessels are to be built with great expedition and entirely of Japanese material. The steel work will be supplied by the Government steel works at Yedamitsu, while the guns will be made by the Kure Arsenal, and the torpedoes and torpedo tubes by various naval arsenals in Japan. It is expected that these vessels will be completed by the end of March next year; that is, in about 200 days. The *Sakura*, the keel of which was laid in 1910 took about 14 months to complete.—"Shipbuilding and Shipping Record."

BOOKS RECEIVED.

THE NAVAL CONSTRUCTOR, by G. SIMPSON, M. I. N. A. Third edition, entirely revised; 819 pages; 364 illustrations. Published by D. VAN NOSTRAND CO. Price, $5.00.

This handbook was prepared with the object of providing a ready reference for students, naval architects, shipbuilders and owners, superintendents, engineers and draughtsmen, engaged in the design, construction or maintenance of ships.

The contents treat of ship calculations, strength of materials, fittings and details, rigging and ropes, equipment, etc. In revision obsolete matter has been eliminated and the whole text brought up to the standard of present-day requirements. —H. C. D.

SCIENTIFIC MANAGEMENT. A collection of the more significant articles describing the Taylor system of management. Edited by CLARENCE BERTRAND THOMPSON, LL. B., A. M. CAMBRIDGE, HARVARD, UNIVERSITY PRESS. 878 pages.

This book is a collection of a large number of articles and essays on the above subject carefully edited and supplied with complete references. It brings together under one binding matter that has appeared from time to time from a great variety of sources. It should be of special interest to managers and all students of scientific management.—H. C. D.

OBITUARY.

WILLIAM STURTEVANT MOORE.

Commodore William Sturtevant Moore, U. S. N., a member of this Society, died at Duxbury, Mass., July 12, 1914, was interred at Arlington National Cemetery on Wednesday, September 16, at half-past two o'clock.

Commodore Moore was one of the first class of "cadet engineers" to have a course at the U. S. Naval Academy. He served with distinction on many of the vessels of the old and new Navy. His last active duty was as engineer officer of the Navy Yard, Boston. He will be pleasantly remembered by many of the members of the Society who have been so fortunate as to have served with him.

ASSOCIATION NOTES.

The annual meeting of the Society was held on October 6, 1914. The following nominations were made for officers for 1915:

For President:

Captain Emil Theiss, U. S. N.
Captain S. S. Robison, U. S. N.

For Secretary-Treasurer:

Lieutenant A. T. Church, U. S. N.

For Members of Council:

Captain B. C. Bryan, U. S. N.
Engineer-in-Chief C. A. McAllister, U. S. R. C. S.
Commander U. T. Holmes, U. S. N.
Lieutenant Commander F. L. Pinney, U. S. N.
Lieutenant Commander J. O. Richardson, U. S. N.
Lieutenant W. T. Conn, U. S. N.

The election will be held on December 30, 1914.

It was decided to submit the question of giving a banquet during the year 1915 to a vote of the members.

The following members and associates have joined the Society since the publication of the last JOURNAL.

MEMBERS.

Bernhard, Alvah D., Lieutenant, U. S. N.
Berrien, Frank D., Lieutenant Commander, U. S. N.
Borland, John, Lieutenant, U. S. N.
Burt, Charles P., Lieutenant Commander, U. S. N. (Ret.).
Clarke, Vincent A., Ensign, U. S. N.
Cleary, Francis J., Lieutenant, U. S. N.
Conn, William T., Lieutenant, U. S. N.
Cooke, Henry D., Lieutenant, U. S. N.
Cooper, Henry G., Lieutenant, U. S. N.

Daubin, Freeland A., Ensign, U. S. N.
Davidson, Lyal A., Ensign, U. S. N.
Davy, Charles G., Lieutenant, U. S. N.
Denfeld, Louis E., Ensign, U. S. N.
Earle, John B., Lieutenant, U. S. N.
Early, Charles W., Lieutenant, U. S. N.
Gatch, Thomas L., Ensign, U. S. N.
Guthrie, Edwin, Lieutenant, U. S. N.
Harrison, Paul H., Second Lieutenant, U. S. R. C. S.
Heron, Kenneth, Lieutenant, U. S. N.
Hoogewerff, John A., Captain, U. S. N.
Jacobs, Randall, Lieutenant, U. S. N.
Johnson, Frank E., Ensign, U. S. N.
Kauffman, James L., Lieutenant, U. S. N.
Keller, Charles S., Lieutenant, U. S. N.
Krauss, Sydney M., Lieutenant, U. S. N.
Latimer, Julian L., Commander, U. S. N.
Lindley, Leonard N., Ensign, U. S. N.
Linsley, Leo L., Ensign, U. S. N.
McConnell, Riley T., Lieutenant, U. S. N.
McDonald, Lewis H., Ensign, U. S. N.
McGill, Clarence M., Lieutenant, U. S. N.
McKinney, Stephen B., Lieutenant, U. S. N.
McMillin, California C., First Lieutenant of Engineers, U. S. R. C. S.
Noyes, Leigh, Lieutenant, U. S. N.
Poe, Baylis F., Ensign, U. S. N.
Powell, Paulus P., Ensign, U. S. N.
Pryor, Francis C., Lieutenant, U. S. N.
Reeves, John W., Jr., Ensign, U. S. N.
Shute, Isaac C., Lieutenant, U. S. N.
Slayton, Charles C., Lieutenant, U. S. N.
Smith, Charles E., Lieutenant, U. S. N.
Smyth, William W., Lieutenant, U. S. N.
Staley, John B., Lieutenant, U. S. N.
Tarrant, William T., Lieutenant Commander, U. S. N.
Vroom, Guysbert B., Ensign, U. S. N.

Williams, Henry, Naval Constructor, U. S. N.
Willson, James D., Lieutenant, U. S. N.
Withers, Thomas, Jr., Lieutenant, U. S. N.
Woodson, Eugene M., Lieutenant, U. S. N.

ASSOCIATES.

Cunningham, H. Y., Master Mechanic, Navy Yard, Charleston, S. C.
Steedman, John H., Vice President, Curtis & Co. Manufacturing Co.; St. Louis, Mo. Residence, 401 N. Newstead Avenue, St. Louis, Mo.

ASSOCIATION NOTES.

The annual meeting of the Society was held on October 6, 1914. The following nominations were made for officers for 1915:

For President:

Captain Emil Theiss, U. S. N.
Captain S. S. Robison, U. S. N.

For Secretary-Treasurer:

Lieutenant A. T. Church, U. S. N.

For Members of Council:

Captain B. C. Bryan, U. S. N.
Engineer-in-Chief C. A. McAllister, U. S. R. C. S.
Commander U. T. Holmes, U. S. N.
Lieutenant Commander F. L. Pinney, U. S. N.
Lieutenant Commander J. O. Richardson, U. S. N.
Lieutenant W. T. Conn, U. S. N.

The election will be held on December 30, 1914.

It was decided to submit the question of giving a banquet during the year 1915 to a vote of the members.

The following members and associates have joined the Society since the publication of the last JOURNAL.

MEMBERS.

Bernhard, Alvah D., Lieutenant, U. S. N.
Berrien, Frank D., Lieutenant Commander, U. S. N.
Borland, John, Lieutenant, U. S. N.
Burt, Charles P., Lieutenant Commander, U. S. N. (Ret.).
Clarke, Vincent A., Ensign, U. S. N.
Cleary, Francis J., Lieutenant, U. S. N.
Conn, William T., Lieutenant, U. S. N.
Cooke, Henry D., Lieutenant, U. S. N.
Cooper, Henry G., Lieutenant, U. S. N.

Daubin, Freeland A., Ensign, U. S. N.
Davidson, Lyal A., Ensign, U. S. N.
Davy, Charles G., Lieutenant, U. S. N.
Denfeld, Louis E., Ensign, U. S. N.
Earle, John B., Lieutenant, U. S. N.
Early, Charles W., Lieutenant, U. S. N.
Gatch, Thomas L., Ensign, U. S. N.
Guthrie, Edwin, Lieutenant, U. S. N.
Harrison, Paul H., Second Lieutenant, U. S. R. C. S.
Heron, Kenneth, Lieutenant, U. S. N.
Hoogewerff, John A., Captain, U. S. N.
Jacobs, Randall, Lieutenant, U. S. N.
Johnson, Frank E., Ensign, U. S. N.
Kauffman, James L., Lieutenant, U. S. N.
Keller, Charles S., Lieutenant, U. S. N.
Krauss, Sydney M., Lieutenant, U. S. N.
Latimer, Julian L., Commander, U. S. N.
Lindley, Leonard N., Ensign, U. S. N.
Linsley, Leo L., Ensign, U. S. N.
McConnell, Riley T., Lieutenant, U. S. N.
McDonald, Lewis H., Ensign, U. S. N.
McGill, Clarence M., Lieutenant, U. S. N.
McKinney, Stephen B., Lieutenant, U. S. N.
McMillin, California C., First Lieutenant of Engineers, U. S. R. C. S.
Noyes, Leigh, Lieutenant, U. S. N.
Poe, Baylis F., Ensign, U. S. N.
Powell, Paulus P., Ensign, U. S. N.
Pryor, Francis C., Lieutenant, U. S. N.
Reeves, John W., Jr., Ensign, U. S. N.
Shute, Isaac C., Lieutenant, U. S. N.
Slayton, Charles C., Lieutenant, U. S. N.
Smith, Charles E., Lieutenant, U. S. N.
Smyth, William W., Lieutenant, U. S. N.
Staley, John B., Lieutenant, U. S. N.
Tarrant, William T., Lieutenant Commander, U. S. N.
Vroom, Guysbert B., Ensign, U. S. N.

Williams, Henry, Naval Constructor, U. S. N.
Willson, James D., Lieutenant, U. S. N.
Withers, Thomas, Jr., Lieutenant, U. S. N.
Woodson, Eugene M., Lieutenant, U. S. N.

ASSOCIATES.

Cunningham, H. Y., Master Mechanic, Navy Yard, Charleston, S. C.

Steedman, John H., Vice President, Curtis & Co. Manufacturing Co.; St. Louis, Mo. Residence, 401 N. Newstead Avenue, St. Louis, Mo.